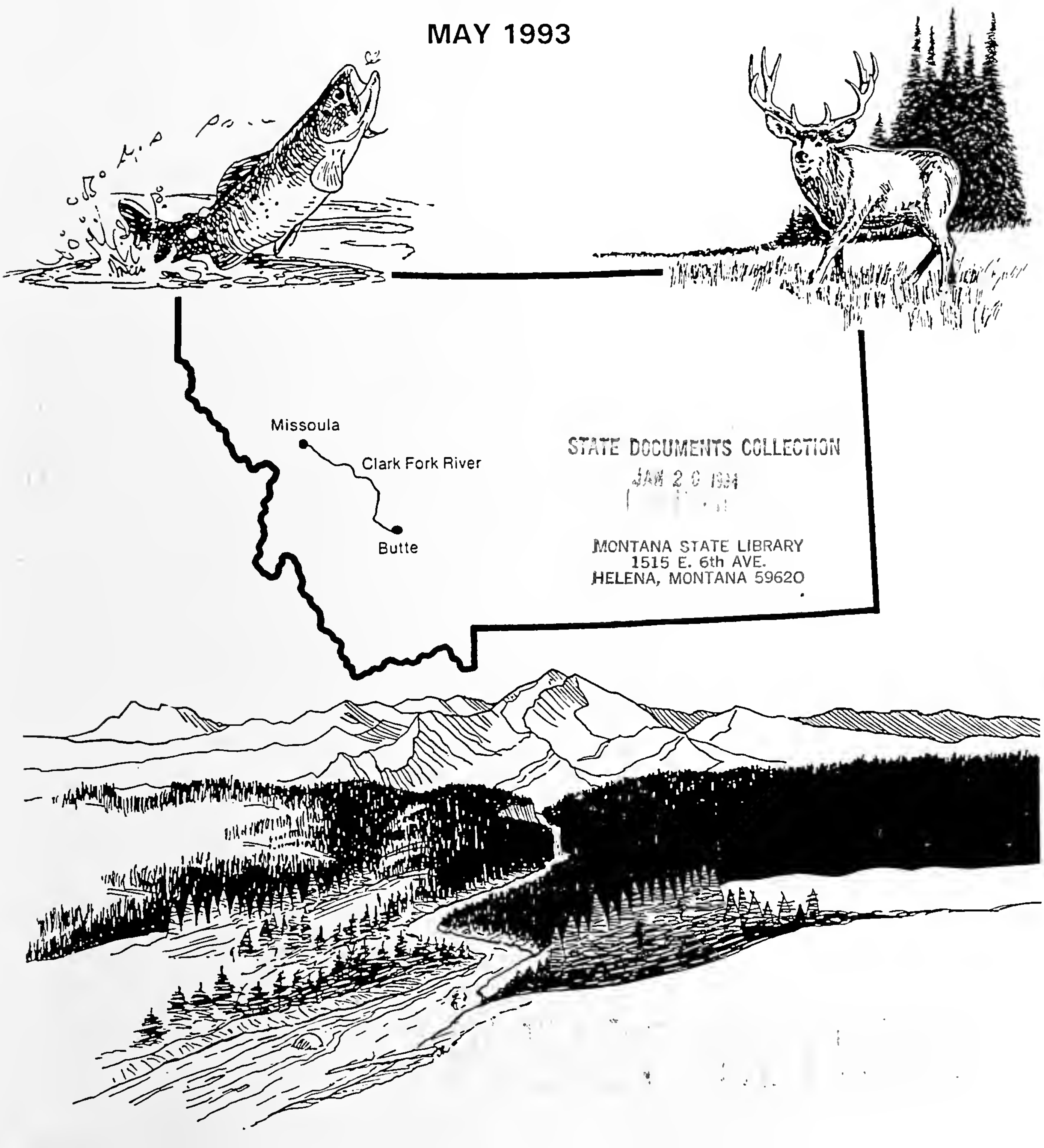
STATE OF MONTANA
NATURAL RESOURCE DAMAGE PROGRAM

GROUNDWATER RESOURCES
INJURY ASSESSMENT REPORTS

UPPER CLARK FORK RIVER BASIN

MAY 1993



SUMMARY AND OVERVIEW:

GROUNDWATER INJURY ASSESSMENT REPORTS

CLARK FORK RIVER BASIN
MONTANA

1.0 INTRODUCTION

This is a summary and overview of the accompanying reports. These reports were prepared to assess injuries to groundwater resources in the Upper Clark Fork River Basin from releases of hazardous and deleterious substances as a consequence of mining and mineral processing operations in the Butte and Anaconda regions. Each injury assessment report was prepared by expert consultants employed by the State of Montana for purposes of its Natural Resource Damage Assessment. This damage assessment was undertaken, in accordance with U. S. Department of Interior regulations, 43 C.F.R. Part 11, and proposed regulations at 56 Fed. Reg. 19752, et seq. (April 29, 1991), in the context of the lawsuit, State of Montana v. Atlantic Richfield Company.[1] Subsequently the parties to that litigation entered into a Memorandum of Understanding (MOU), effective March 16, 1993 which provides for a negotiation process in an attempt to settle the lawsuit. This summary and overview and the accompanying assessment reports are being released pursuant to the MOU.

The following groundwater injury assessment reports are the subject of this summary and overview:

1. "Butte Groundwater Injury Assessment Report," by Dr. Ann S. Maest of RCG/Hagler, Bailly, Inc., and John J. Metesh of Montana Bureau of Mines and Geology, dated April, 1993.

2. "Anaconda Groundwater Injury Assessment Report," by Dr. William W. Woessner of the University of Montana, dated February 20, 1993.

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[1] The State of Montana commenced an action against the Atlantic Richfield Company ("ARCO") in the United States District Court for the District of Montana (Case No. CV-83-317-HLN-PGH) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), and the Montana Comprehensive Environmental Cleanup and Responsibility Act ("CECRA"). The lawsuit seeks the recovery of damages for injuries to natural resources for which the State is trustee in the Upper Clark Fork River Basin resulting from releases of hazardous and deleterious substances from facilities for which ARCO is the responsible party.

3. "Milltown Groundwater Injury Assessment Report," by Dr. William W. Woessner of the University of Montana, dated March 10, 1993.

4. "Montana Pole Treatment Plant Groundwater Injury Assessment," by John J. Metesh of the Montana Bureau of Mines and Geology, dated April, 1993.

5. "Rocker Groundwater Injury Assessment Report," by Dr. William W. Woessner of the University of Montana, dated January 22, 1993.

1.1 Site Descriptions of Groundwater Resource Areas

The injury assessment reports deal with five regions where groundwater resources have been injured by releases of hazardous substances from ARCO facilities (See Figure 1-1):

(1) Butte Groundwater Resource Area. This area, which is located in the City of Butte, has two injured aquifers. Injured groundwater in the Butte Hill bedrock aquifer occurs within fractures, joints, and faults in the bedrock and in the underground mine workings. A significant quantity of contaminated water from this aquifer has also flowed into the Berkeley Pit. Injured groundwater in the alluvial aquifer occurs primarily in the upper 40 feet of the aquifer near the Berkeley Pit and between the Pit and Silver Bow Creek at the downstream end of Colorado Tailings.

(2) Anaconda Groundwater Resource Area. This area, located in the Deer Lodge Valley, includes portions of the City of Anaconda, Opportunity Ponds and Warm Springs Ponds. There are two injured aquifers: the bedrock aquifer under Smelter Hill and the alluvial aquifer underlying a large area from the City of Anaconda to Warm Springs Ponds.

(3) Milltown Groundwater Resource Area. This area, located adjacent to Milltown Dam some five miles east of the City of Missoula, includes the dam's reservoir area and a portion of the town of Milltown. The injured groundwater is contained in the reservoir sediments and in the sand, gravel and cobble aquifer underneath these sediments and Milltown.

(4) Montana Pole Groundwater Resource Area. This area is the former site of the Montana Pole Treatment Facility. It is located in the southwest portion of the City of Butte just south of Silver Bow Creek; Interstate 90 runs through the site. As a result of facility operations, organic hazardous substances were released to the soils and to the groundwater below the site.

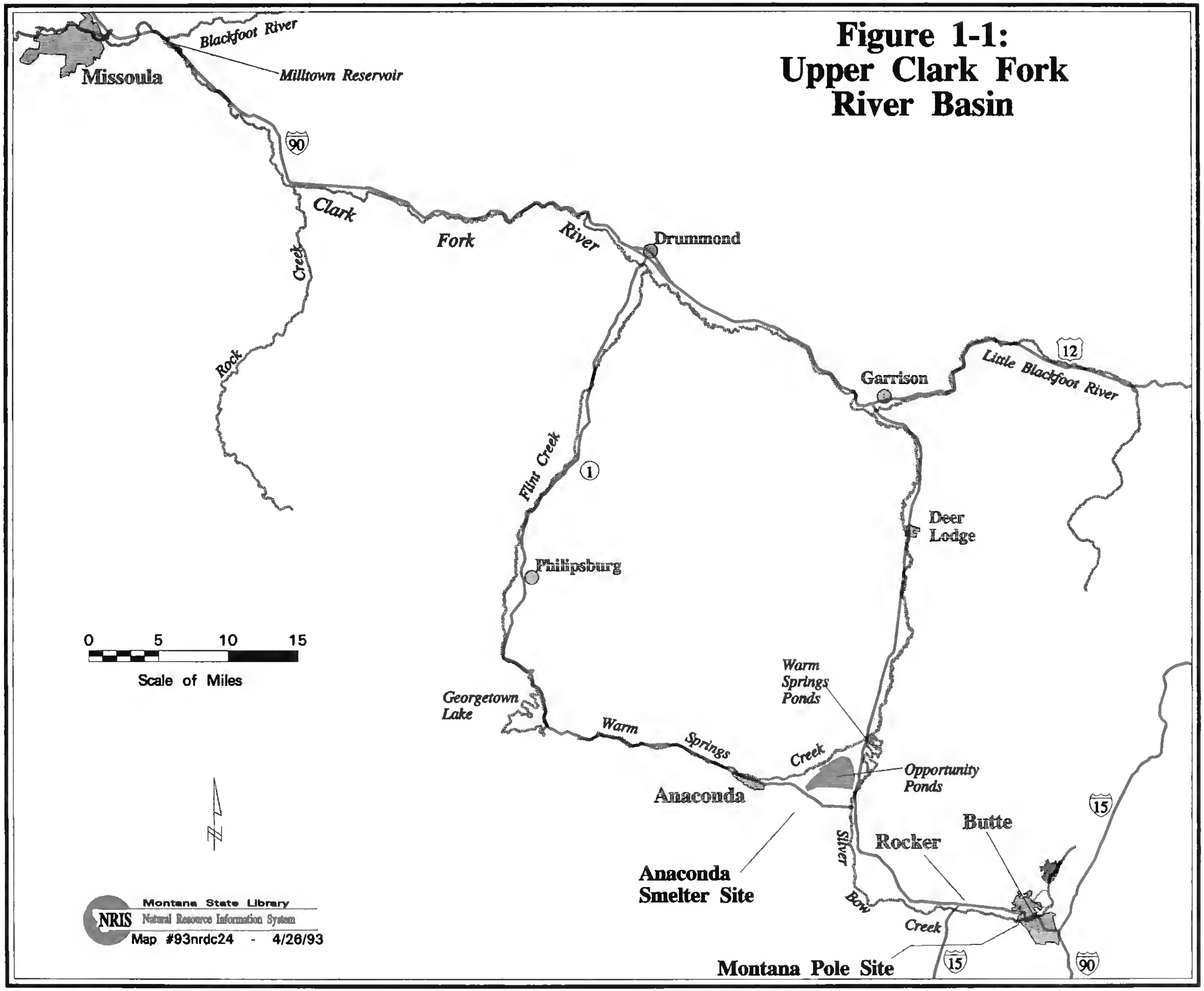
Figure 1-1:
Upper Clark Fork
River Basin
Missoula
Blackfoot River
Milltown Reservoir
90
Clark
Fork
River
Creek
Rock
Drummond
Garrison
12
Little Blackfoot River
Flint Creek
1
Deer
Lodge
Philipsburg
0
5
10
15
Scale of Miles
Georgetown
Lake
Warm
Springs
Creek
Warm
Springs
Ponds
Opportunity
Ponds
Anaconda
Anaconda
Smelter Site
Silver
Bow
Creek
Rocker
Butte
15
Montana Pole Site
15
90
Montana State Library
NRIS Natural Resource Information System
Map #93nrdc24 - 4/26/93

(5) Rocker Groundwater Resource Area. This is the former site of the Rocker Timber Framing and Treating Plant. It is located near Silver Bow Creek seven miles west of Butte at the town of Rocker. As a result of plant operations, hazardous substances were released to the soils and to the groundwater below the site.

It should be noted that none of the above reports address the contaminated groundwater associated with the Clark Tailings, which are located in Butte about one mile south of the Montana Pole site. (See Hydrometrics, April 1983, "Summit and Deer Lodge Valleys - Long Term Environmental Rehabilitation Study - Butte-Anaconda, Montana, Vol. IV - Clark Tailings.") The accompanying assessment reports also do not deal with the extent of contamination, or potential contamination, associated with, or potentially associated with, the Yankee Doodle Tailings Ponds. Adequate data on the extent of groundwater injury associated with the Clark and Yankee Doodle tailings are not yet available. Furthermore, the adequacy of the Yankee Doodle Tailings Dam to withstand a maximum potential seismic event remains the subject of continued investigation. Studies do indicate that ponded water and tailings, if released by a hypothetical failure of the dam, generally would flow into the Berkeley Pit. (See International Engineering Co., August 1981, "Geotechnical and Hydrologic Studies - Yankee Doodle Tailings Dam, Butte, Montana."). The State of Montana reserves its rights regarding this contamination and potential contamination.

1.2 Montana's Trusteeship Over Groundwater

Groundwater is a natural resource which is owned by the State of Montana in trust for the people of the State. Montana's "trusteeship" over groundwater resources is provided for, and confirmed by, numerous legal authorities.[2] Those authorities include:

(1) "All surface, underground, flood, and atmospheric waters within the boundaries of the state are the property of the state for the use of its people and are subject to appropriation for beneficial uses as provided by law." (Mont. Const. Art. IX, § 3(3).)

(2) "The legislature shall provide for the administration, control, and regulation of water rights and shall establish a system of centralized records, in addition to the present system of local records." (Mont. Const. Art. IX, § 3(4).)

[2] The term, "trusteeship", is used here as it is used in CERCLA, 42 U.S.C.§9607(f)(2)(B). Natural resources located within a state are within the "trusteeship" of such state if they are owned or held in trust, or managed or controlled by, or appertain to, such state. (42 U.S.C.§9601(16).)

(3) The public trust doctrine in Montana provides that all underground waters are owned by the state for the benefit of its people. (Galt v. Montana Dept. of Fish, Wildlife & Parks, 731 P.2d 912, 914-15 (Mont. 1987). Also see Intel Corp. v. Hartford Acc. & Indem. Co. 692 F. Supp. 1171, 1183-1189 (ND Cal. 1988), aff'd. 952 F.2d 1551,1565 (9th Cir. 1991).)

(4) "Pursuant to Article IX of the Montana Constitution, the legislature declares that any use of water is a public use and that the waters within the state are the property of the state for the use of its people and are subject to appropriation for beneficial uses. . . ." (Mont. Code Ann. § 85-2-101(1).)

(5) "The general welfare of the people of Montana, in view of the state's population growth and expanding economy, requires that water resources of the state be put to optimum beneficial use and not wasted." (Mont. Code Ann. § 85-1-101(1).)

(6) "The state, in the exercise of its sovereign power . . . shall coordinate the development and use of the water resources of the state so as to effect full utilization, conservation, and protection of its water resources." (Mont. Code Ann. § 85-1-101(3).)

(7) "The water resources of the state must be protected and conserved to assure adequate supplies for public recreational purposes and for the conservation of wildlife and aquatic life." (Mont. Code Ann. § 85-1-101(5).)

(8) "The public interest requires the construction, operation, and maintenance of a system of works for the conservation, development, storage, distribution, and utilization of water, which construction, operation, and maintenance is a single object and is in all respects for the welfare and benefit of the people of the state." (Mont. Code Ann. § 85-1-101(6).)

(9) "The legislature recognizes that water is one of the most valuable and important renewable resources in Montana. . ." (Mont. Code Ann. §§ 85-1-601(3).)

(10) "The Legislature finds that: (a) Montana's citizens depend on groundwater for a variety of uses, including domestic, agricultural, industrial, irrigation, mining, municipal, power, and recreation, and for maintenance of ecosystems and surface water supplies. . ." (Mont. Code Ann. § 85-2-902(1).)

(11) "It is the public policy of the State to: (1) conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses; (2) provide a comprehensive program for the

prevention, abatement, and control of water pollution." (Mont. Code Ann. § 75-5-101.)

(12) "It is unlawful to: (a) cause pollution of any state waters or to place or cause to be placed any wastes in a location where they are likely to cause pollution of any state waters. . ." (Mont. Code Ann. § 75-5-605.)

(13) The people of the State of Montana have a constitutional right to "a clean and healthful environment," and the State and each person in the State shall "maintain and improve" such environment" for present and future generations." Furthermore, "all lands disturbed by the taking of natural resources shall be reclaimed." (Mont. Const. Art. II § 3, and Art IX §§ 1(1) and 2(1).)

The above listed authorities are not exclusive, and there are additional constitutional, statutory, regulatory, judicial and common-law authorities indicative of Montana's trusteeship for groundwater resources.

1.3 <u>Injury Definitions Applicable to Groundwater Resources</u>

The term, "injury", is defined in the Department of Interior Regulations as:

> A measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a . . . release of a hazardous substance, or exposure to a product of reactions resulting from . . . a release of a hazardous substance. (43 CFR § 11.14(v).)

Thus a natural resource, such as groundwater, is "injured" if it has suffered a measurable adverse change in its quality as a result (either direct or indirect) of its exposure to a release of a hazardous substance, or as a result (either direct or indirect) of its exposure to a product of reactions resulting from a release of a hazardous substance.

Specific injury definitions for groundwater resources are set forth in the regulations at 43 CFR § 11.62(c). This section provides that "injury" to groundwater occurs when certain excess concentrations of contaminants are detected in groundwater samples:

> (1) An injury to the groundwater resource has resulted from a . . . release of a hazardous substance if one or more of the following changes in the physical or chemical quality of the resource is measured:

> (i) Concentrations of substances in excess of drinking water standards, established by . . . the SDWA [Safe Drinking Water Act], or by other Federal or State laws or regulations that establish such standards for drinking water, in groundwater that was potable before the . . . release;
>
> . . .
>
> (iv) Concentrations of substances sufficient to have caused injury . . . to surface water, air, geologic or biologic resources, when exposed to groundwater.

In addition, 43 CFR § 11.62(c) describes the circumstances under which an "injury" to groundwater can occur where no hazardous substances are detected in the groundwater samples:

> (4) In those instances when injury is determined and no . . . hazardous substance is detected in samples from the groundwater resource, it must be demonstrated that the substance causing the injury occurs or has occurred in the groundwater resource as a result of physical, chemical, or biological reactions initiated by the . . . release of hazardous substances.

The relevant standards for groundwater injury thus include primary drinking water standards, i.e. maximum contaminant levels and goals (MCLs, MCLGs), and the secondary drinking water standards (SMCLs), established under the Safe Drinking Water Act and Montana State Law. These standards are listed in Table 1-1.

Along with "hazardous substances," Table 1-1 also lists other substances which may be used to demonstrate "injury" in groundwater but which are not defined as hazardous under CERCLA.[3] These other substances, which also are derived from mining and processing operations in the Butte and Anaconda areas, include sulfate, aluminum, iron and manganese. In order to establish that these substances cause "injury", as defined in the regulations, it must be demonstrated that these substances occur in the groundwater in concentrations in excess of drinking water standards as a result or product of physical, biological or chemical reactions resulting from, or initiated, by the release of hazardous substances. (43 CFR § 11.62(c)(4) and § 11.14(v).)

Acid mine drainage, which is the cause of a good deal of the contamination described in the accompanying groundwater reports, can dissolve metal sulfide and alumino-silicate minerals and release sulfate, sulfuric acid, metals and metalloids to the

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[3] See 40 CFR § 302.4 for a list of CERCLA hazardous substances.

Table 1-1
Primary and Secondary Drinking Water Standards
(μg/l Except Where Noted)

Contaminant	MCL	MCLG	SMCL
Aluminum	--	--	50-200
Antimony[1]	6	6	--
Arsenic[2]	50	50	--
Barium	2,000/1,000[6]	2,000	--
Beryllium[1]	42	4	--
Cadmium	5/10[6]	5	--
Chromium	100/50[6]	100	--
Copper[3]	TT[4]	1,300	1,000
Fluoride	4,000	4,000	2,000
Iron	--	--	300
Lead[3]	TT[5]/50[6]	0	--
Manganese	--	--	50
Mercury	2	2	--
Nickel[1]	100	100	--
pH	--	--	6.5-8.5
Selenium	50/10[6]	50	--
Silver	50[6]	--	100
Sulfate (mg/l)	--	--	250
Thallium[1]	2	0.5	--
Zinc	--	--	5,000

1 Effective date = 1/17/94; monitoring requirements currently in effect.
2 Under revision; Proposed MCL/MCLG due September 1994.
3 Treatment technique requirement in effect.
4 Action level = 1300 μg/l.
5 Action level = 15 μg/l (at tap).
6 Montana State drinking water standard.
Source: Safe Drinking Water Act and Montana State Law.

CERCLA §101(22)
release = spilling, leaking, pumping, ... emptying
leaching

environment. The formation of acid mine drainage involves many types of biogeochemical reactions, including: oxidation (both biological and chemical), dissolution, precipitation, hydrolysis and complexation. In addition to the substances listed as hazardous under CERCLA (including arsenic, cadmium, copper, lead, zinc, ferric sulfate, aluminum sulfate and sulfuric acid), dissolved sulfate, aluminum, manganese and iron are formed from the reactions involved in the generation of acid mine drainage. These reactions have been occurring in the underground workings, tailings and waste rock piles at Butte and Anaconda for many years. As a result, groundwaters down-gradient from these source materials are contaminated with such substances (i.e., sulfate, etc.) in addition to heavy metals. Therefore, although sulfate, iron, manganese and aluminum are not specifically listed as hazardous substances under CERCLA, these substances exist in the groundwater in concentrations in excess of drinking water standards, and result from reactions initiated by the release of hazardous substances. Their existence in such concentrations in the groundwaters at issue constitutes injury to those groundwaters.

The first definition of groundwater injury listed above also calls for the groundwater to have been "potable" before the release of hazardous substances. "Potable" generally means that the water was "fit or suitable for drinking". (51 Fed. Reg. 27674, 27707 (1986).) The groundwater injury assessment reports demonstrate that groundwater in each of the resource areas was potable prior to the releases of hazardous substances.

In the Butte area almost all of the wells used in the baseline analyses had median concentrations of hazardous substances well below drinking water standards.[4] In addition, historical and other references indicate that groundwater in the Butte area was and is still being used as drinking water. (E.g., Meinzer, 1914, "The Water Resources of Butte, Montana", USGS Water Supply Paper 345-G.)

In the Anaconda, Milltown, Montana Pole, and Rocker groundwater resource areas, the baseline wells in the vicinity of the injured groundwater resources all had median concentrations of hazardous substances which were significantly below MCLs and SMCLs. This is clear and convincing evidence that the water in these regions was potable prior to the releases of hazardous substances. Historical and current use of the water in these areas also supports this conclusion.

For example, in the Anaconda area, it is known that groundwater wells have been historically used for municipal,

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[4] The exception to this involves the bedrock wells in the active mining area which (due to a lack of other data) were used for baseline. In some of these wells median values exceeded SMCLs to a small degree. These wells, however, were considered to have been in mining impacted areas and, therefore, are not truly representative of baseline conditions.

domestic and agricultural purposes. (See Konizeski, et al, 1968, "Geology and Groundwater Resources of the Deer Lodge Valley Montana," USGS Water Supply Paper 1862; Hydrometrics, Feb. 1981, "Summary of Water Resources in the Vicinity of the Anaconda Company Pond System, Deer Lodge County, Montana.") In fact, the City of Anaconda's municipal water supply comes from three groundwater wells drilled in the alluvial aquifer upgradient of the contaminated plume. (Peccia & Associates, 1991, "Anaconda Water System Improvements Program.") In the Milltown area, groundwater wells surrounding the contaminated plume continue to supply drinking water to residents in the area. Prior to contamination, there were groundwater wells in the plume area which also were used for drinking water purposes.

1.4 Summary of Groundwater Resource Injuries

Groundwater has been injured in aquifers underlying the five study areas. Contaminants in groundwater have also caused injury to geologic resources (soils, aquifer materials) and to surface water, including bed sediments, particularly in Silver Bow Creek.

1. Butte Groundwater Resource Area. Both the bedrock and alluvial aquifers in this area are injured by releases of antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, zinc and sulfides of copper, arsenic, zinc, lead, silver, and antimony. The sources of groundwater contamination in the Butte area are the past mining and processing operations in the Butte area, including the Berkeley Pit, which have left large areas of tailings, waste dumps and underground workings which continue to release hazardous substances to groundwater. The combined areal extent of the injured bedrock and alluvial aquifers in Butte is almost nine square miles. The present volume of injured groundwater in this study area is approximately 205,000 acre-feet.

2. Anaconda Groundwater Resource Area. Both the bedrock and alluvial aquifers in this area are injured by releases of arsenic, cadmium, chromium, copper, lead, mercury, and zinc. The sources of groundwater contamination are the mining and processing related wastes (which total more than 750 million cubic yards) in the vicinity of Smelter Hill, the Old Works, the Anaconda Tailings Ponds, the Opportunity Tailings Ponds and Warm Springs Ponds. The areal extent of the injured alluvial aquifer in the Deer Lodge Valley is more than 25 square miles. The volume of injured groundwater is approximately 327,400 acre-feet.

3. Milltown Groundwater Resource Area. The six million cubic yards of contaminated sediments behind the dam, which migrated downstream from their original mining and processing sources in Butte and Anaconda, have released arsenic and other hazardous substances to groundwater and have caused injury. The

areal extent of the injured aquifer is about one square mile; and the volume of injured groundwater contained within the contaminated plume is approximately 4410 acre-feet.

4. Montana Pole Groundwater Resource Area. Groundwater in the alluvial aquifer in this area has been injured by releases of hazardous substances from the Montana Pole Treatment Plant, including: phenols, including PCP, polynuclear aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, xylene, 2-methylnapthalene, dioxins, furans, and DDT. The areal extent of this injury is about 44 acres; and the volume of injured groundwater contained within the contaminated plume is approximately 350 acre-feet.

5. Rocker Groundwater Resource Area. Groundwater in the alluvial aquifer in this area has been injured by releases of arsenic, cadmium, copper, lead, zinc, PAHs, benzene and bis (2-ethylhexyl) phthalate from the Rocker Timber Framing and Treating Plant. The areal extent of this injury is about 20 acres; and the volume of injured groundwater contained within the contaminated plume(s) is approximately 202 acre-feet.

Table 1-2
Summary of Areal Extent and Estimated Volume of Injured Groundwater

RESOURCE AREA	AREAL EXTENT (Square Miles)	VOLUME (acre-feet)
Butte	9.0	205,000*
Anaconda	<25.0	327,400
Milltown	1.0	4,410
Montana Pole	.07	350
Rocker	.03	202

*Includes some 64,000 acre-feet of water in the Berkeley Pit.

1.5 Peer Reviewers and Other Experts Consulted

The MOU between the State and ARCO provides for the "identification of consultants and/or experts who support the claim of injury." Obviously, the principal authors of the groundwater injury assessment reports would fall within this category. There are, in addition, a number of other expert consultants who participated to a more limited degree in the preparation, or review of, one or more of the groundwater reports. Those individuals include the following: Dr. Paul Witherspoon, Professor Emeritus of

Geological Engineering, and Dr. Richard Brand, Professor of Biostatistics, University of California, Berkeley; Dr. D. Kirk Nordstrom, Research Hydrogeochemist, U.S.G.S. Boulder, Colorado; Dr. Charles Alpers, Research Chemist, U.S.G.S. Sacramento, California; James Madison and Ginette Abdo, Assistant Research Hydrogeologists, and Ted Duaime, Associate Research Hydrogeologist, Montana Bureau of Mines and Geology, Butte; and Dr. John L. Sonderegger, Professor of Hydrogeology, Montana College of Mineral Science and Technology, Butte, Montana.

2.0 BUTTE GROUNDWATER RESOURCES

2.1 Introduction and Site Description

This section is a summary and overview of the "Butte Groundwater Injury Assessment Report" by Dr. Ann Maest and John Metesh, dated April, 1993. This report involves an assessment of groundwater injuries occurring principally in the Butte Mine Flooding Operable Unit and the Area One Operable Unit.

The Butte Mine Flooding Operable Unit extends from the Continental Divide on the east side to Missoula Gulch on the west side and from the Yankee Doodle Tailings Pond on the north side to Silver Bow Creek on the south side. (See Figure 2-1.) The major features of the site include: The Yankee Doodle Tailings Pond; leach pads area; the Berkeley Pit; underground mine shafts and workings; and waste rock dumps. The underground mines in Butte were separated into the East Camp and West Camp in the early 1960s by concrete bulkheads to reduce the volume of water that had to be pumped to keep the central mines working. The East Camp includes the Berkeley Pit, the Kelley, Anselmo, Belmont, Chester, Granite Mountain, Lexington and Steward mines, and associated underground mine workings. The West Camp includes the Emma and Travona mines.

The Area One Operable Unit extends from below the Montana Resources (MR) Concentrator (formerly the Weed Concentrator) parallel to the Metro Storm Drain and Silver Bow Creek to the Colorado Tailings. (See Figure 2-1.) The Colorado Tailings/Butte Reduction Works vicinity is referred to as Lower Area One. The main features of this site include: The buried Parrott Tailings (near and under the City-County Shop Complex area); Metro Storm Drain; Silver Bow Creek and Blacktail Creek; the Butte Reduction Works area; and the Colorado Tailings.

2.1.1 Geology of the Study Area

Mountains in the upper Silver Bow Creek basin are composed predominantly of quartz monzonite, which is a silica-rich plutonic

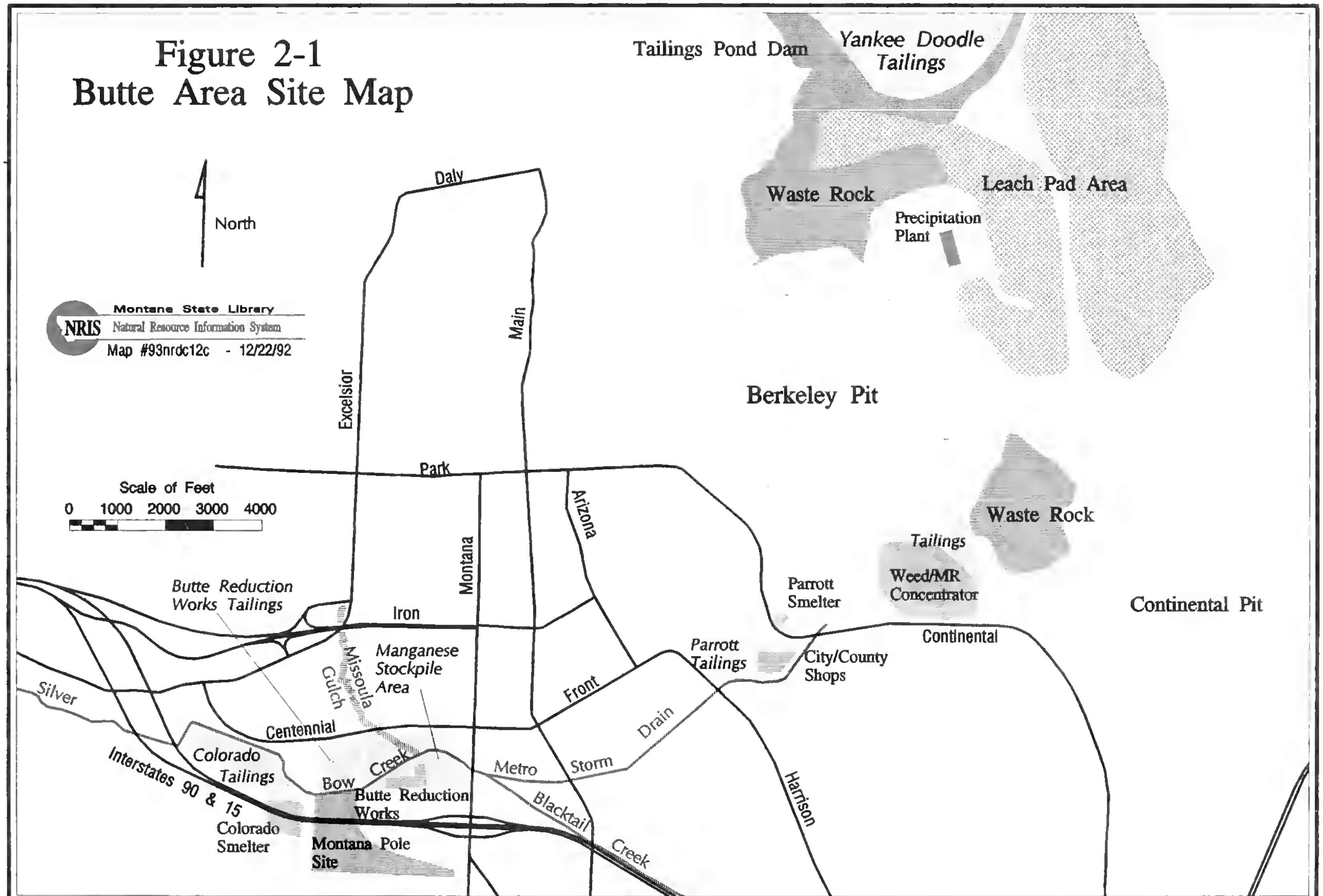


Figure 2-1
Butte Area Site Map
North
Montana State Library
NRIS Natural Resource Information System
Map #93nrdc12c - 12/22/92
Scale of Feet
0 1000 2000 3000 4000
Tailings Pond Dam
Yankee Doodle Tailings
Waste Rock
Leach Pad Area
Precipitation Plant
Berkeley Pit
Waste Rock
Tailings
Weed/MR Concentrator
Continental Pit
Parrott Smelter
Continental
Parrott Tailings
City/County Shops
Daly
Main
Excelsior
Park
Montana
Arizona
Iron
Front
Drain
Storm
Metro
Harrison
Blacktail
Creek
Butte Reduction Works Tailings
Manganese Stockpile Area
Missoula Gulch
Centennial
Silver
Colorado Tailings
Bow
Creek
Butte Reduction Works
Interstates 90 & 15
Colorado Smelter
Montana Pole Site

rock (rocks formed from subsurface magma) in the granite family. The rocks are part of a granitic mass known as the Boulder Batholith, which extends southwesterly from Helena to the Big Hole River in Beaverhead County.

The City of Butte is named for Big Butte, a remnant volcanic vent complex that emitted the rhyolite (a fine-grained equivalent of granite) that drapes the northwestern part of the upper Silver Bow Creek basin. Younger rhyolitic and quartz-porphyry plugs and dikes intrude the quartz monzonite and are often associated with ore deposits. The quartz monzonite and the Boulder Batholith in general were formed over a 10-million year period (78-68 million years ago) during late Cretaceous time.

More recent unconsolidated Quaternary and semiconsolidated Tertiary valley fill and alluvial deposits line the Silver Bow Creek/Metro Storm Drain area and Lower Area One. The deposits overlie, and are derived in part from weathering of, the quartz monzonite bedrock and range from over 300 feet thick near the MR Concentrator to less than 30 feet beneath the Colorado Tailings. A north-south trending bedrock trough east of the Berkeley Pit contains several hundred feet of alluvial deposits. The steep drop-off of the bedrock surface by Montana Street may be due to the presence of a normal fault, which brings quartz monzonite bedrock to within 50 feet of the ground surface.

2.1.2 Hydrogeology of the Study Area

Groundwater in the bedrock aquifer occurs predominantly within fractures, joints and faults in the quartz monzonite and in the underground mine workings. A weathered and leached zone is present in the upper 200 feet, or so, of bedrock. Before dewatering, depth to groundwater ranged from 20 to 100 feet in the vicinity of the Berkeley Pit, and the groundwater flow direction was from north to south. Currently, a large cone of depression exists around the Berkeley Pit, and groundwater in bedrock flows toward and into the pit. Groundwater in the alluvial aquifer is recharged from precipitation, snowmelt runoff, streams and artificial recharge. Groundwater in the aquifer beneath Area One generally flows from east to west and discharges to Blacktail Creek and Silver Bow Creek. The cone of depression around the Berkeley Pit, however, moves alluvial groundwater in that vicinity towards the pit.

2.2 Groundwater Injury Determination

2.2.1 Sources of Hazardous Substances

Both primary and secondary sources release hazardous substances to groundwater in the study area. Primary sources are directly derived from mining, processing or disposal practices and

include: The underground mine workings; tailings; and waste rock piles. Secondary sources are the result of reworking of primary sources of contamination by physical (i.e., transport in surface water) or chemical (i.e., leaching) mechanisms. Secondary sources of contamination include: streamside tailings; soils and aquifer materials contaminated by primary sources; surface salts; smelter airfall; and acid mine drainage.

Table 2-1
Sources of Groundwater Contamination and Identity of Hazardous Substances

Contaminant Source	Hazardous Substances Identified
Underground mine workings and pit walls; acid mine drainage	Ag, As, Cd, Cu, Ni, Pb, Sb, V, Zn, sulfides
Waste Rock Piles near Berkeley Pit	Ag, As, Cr, Cu, Pb, Se, V, Zn, sulfides
Buried Parrot Tailings	Ag, As, Cd, Cu, Hg, Pb, Sb, V, Zn, sulfides
Colorado Tailings	Ag, As, Cd, Cr, Hg, Ni, Pb, Sb, Se, V, Zn, sulfides
Butte Reduction Works Tailings	Ag, As, Cd, Cr, Cu, Ni, Pb, Sb, V, Zn, sulfides
Manganese stock piles and flue dust	Ag, As, Be, Cd, Cr, Cu, Hg, Pb, Ni, Sb, Se, Tl, V, Zn
Slag, Slag Sand and Gravel	Ag, As, Be, Cd, Cu, Pb, Ni, Sb, V, Zn
Railroad Bed Fill	Ag, As, Cr, Cu, Pb, Ni, Sb, Se, V, Zn, sulfides
Efflorescent Salts	Cd, Cu, Pb, Zn
Streamside Tailings	Cd, Cu, Pb, Zn, sulfides
Contaminated Soils	Ag, As, Be, Cd, Cr, Cu, Ni, Pb, Sb, Se, V, Zn
Mixed alluvial soils and tailings	Ag, As, Be, Cd, Cr, Cu, Hg, Ni, Pb, Se, Tl, V, Zn
Leach pad solutions	As, Cd, Cr, Cu, Ni, Zn, Sulfuric acid
Weed Concentrator	Cd, Cu, Zn
Sulfuric acid used in underground leaching	Sulfuric acid

Key: Sb=antimony, As=arsenic, Be=beryllium, Cd=cadmium, Cr=chromium, Cu=copper, Ni=nickel, Pb=lead, Hg=mercury, Se=selenium, Ag=silver, Tl=thallium, V=vanadium, Zn=zinc.

A summary of the primary and secondary sources of groundwater contamination, and hazardous substances identified in sources, are listed in Table 2-1. All the major metals and metalloids that are hazardous under CERCLA were found in sources of groundwater contamination in the area. The hazardous substances identified in source materials include: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, zinc, sulfuric acid, and sulfides of several of these hazardous substances (copper, arsenic, zinc, lead, silver, antimony). In addition, dissolved sulfate, aluminum, manganese and iron are formed from generation of acid mine drainage at the Butte site.

2.2.2 Duration of Release

Large scale copper mining began in the Butte region in about 1882. Significant quantities of hazardous substances have been continuously released and re-released from Butte sources since that time. Those releases of hazardous substances continue today.

2.2.3 Pathway Determination

The pathway determination addresses the route and manner of transport of hazardous substances from the source to the location of the injured groundwater resource. The pathway may be determined by demonstrating the presence of hazardous substances in the pathway resource. (43 CFR § 11.63 (a)(2).)

The primary pathways for groundwater contamination in the Butte area are:

1. Infiltration of precipitation and snow melt through sources of contamination in the unsaturated zone, which leaches hazardous substances to down-gradient groundwater;

2. Rising of capillary groundwater to sources of contamination in the unsaturated zone, which leaches and transports hazardous substances to down-gradient groundwater during an infiltration event;

3. Inundation and leaching of source materials in the saturated zone via groundwater flow through sources or changes in groundwater level; and

4. Transport of contaminated water (e.g., from leaking process solutions or contaminated alluvial groundwater) through the unsaturated or saturated

zone to down-gradient groundwater, pit water and surface water.

The first three pathways involve leaching of source materials. Both primary and secondary sources identified in the study area have been shown to leach significant concentrations of hazardous substances to groundwater. The leaching of mineralized material, including efflorescent salts remaining in underground workings, is the primary pathway for contamination of the bedrock aquifer in the Butte Hill area. Formation of acid mine drainage in the underground workings involves leaching of primary source materials that generate significant concentrations of dissolved sulfate, iron, manganese, aluminum and hazardous substances in the mine water.

The fourth pathway has been documented in the vicinity of the MR Concentrator and leach pads area, in the bedrock aquifer below the alluvial aquifer, and in gaining sections of the Metro Storm Drain (MSD) and Silver Bow Creek (SBC). This pathway includes: (1) process solutions from the Weed (or MR) Concentrator; (2) solutions associated with operation of the leach pads; (3) mine and process water pumped from underground workings and precipitation plant to SBC/MSD; (4) sulfuric acid used to leach copper from underground mines; and (5) contaminated alluvial and bedrock groundwater. These solutions and mine waters can be transported: (1) through the unsaturated zone to down-gradient groundwater in either the alluvial or bedrock aquifers; (2) to the Berkeley Pit, and (3) to surface waters in the Metro Storm Drain and Silver Bow Creek.

The Weed (or MR) Concentrator and leach pads have been operational during most times since the 1960s. Groundwater mounding and changes in groundwater level correspond to active and inactive periods at the Concentrator, indicating that the unlined process ponds at the Concentrator were and are leaking to the alluvial aquifer. The contaminated process waters from the leach pad area are being transported the unsaturated zone and contaminating the alluvial groundwater with hazardous substances. This groundwater, containing elevated concentrations of cadmium, copper, iron, zinc and sulfate, is believed to flow through the alluvial aquifer toward the Berkeley Pit.

2.2.4 Injury Determination

Groundwater injuries have occurred in the bedrock aquifer under Butte Hill (and in the Berkeley Pit) and in the alluvial aquifer.

Concentrations of hazardous substances in Berkeley Pit water exceed drinking water standards for pH, sulfate, TDS, fluoride, iron, manganese, aluminum, silver, arsenic, cadmium, copper, nickel, lead and zinc. Bedrock groundwater in the Butte Hill area

exceeds MCL and/or SMCL values for pH, sulfate, TDS, aluminum, arsenic, cadmium, copper, iron, fluoride, lead, manganese, nickel, silver and zinc.

Hazardous substances are also highly elevated in the alluvial groundwater. The alluvial groundwater in the Butte Hill area contains concentrations of iron, cadmium and sulfate that exceed MCLs and SMCLs. Alluvial groundwater in Area One contains concentrations of zinc, sulfate, iron, cadmium, lead, copper, arsenic, aluminum, antimony, beryllium, chromium, fluoride, manganese, nickel and thallium that exceed relevant drinking water standards.

Contaminated groundwater discharges to sections of Silver Bow Creek below Montana Street and to the lower reaches of the Metro Storm Drain from about Harrison Avenue to Blacktail Creek. Directly down-gradient of the Colorado Tailings, groundwater discharges from the alluvial aquifer and further contaminates Silver Bow Creek with hazardous substances. This is defined as an additional "injury" under the DOI regulations because this discharge is causing injury to a surface water resource.

2.3 Groundwater Injury Quantification

2.3.1 Baseline Determination

The following criteria were established to determine baseline groundwater conditions in the alluvial and bedrock aquifers:

- Similar geology to that of impacted areas;
- Similar groundwater flow patterns and system to those of impacted areas;
- Location of baseline wells away from obvious sources of contamination and associated plumes; and
- Consideration of groundwater type and other geochemical indicators that may distinguish uncontaminated from contaminated groundwater.

Using existing data and well data obtained as part of Montana's Natural Resource Damage Assessment, baseline conditions were estimated.

Three bedrock zones were identified for establishing baseline conditions. Median contaminant values for baseline groundwater samples from the composite of these three zones were generally below drinking water standards, and no median concentration exceeded an MCL value.

Mean contaminant concentrations of samples from the unmineralized and weathered/mineralized bedrock zones did not exceed any MCL or SMCL values. However, while the mean contaminant concentrations in the unweathered/mineralized bedrock zone also did not exceed any MCL values, four SMCL values are exceeded: aluminum, iron, manganese and sulfate. The groundwater from which baseline was estimated in the unweathered/mineralized zone is considered to be at least somewhat impacted by mining. The groundwater may also have naturally-occurring elevated concentrations of certain constituents (i.e., iron and manganese). However, the elevated concentrations of sulfate and aluminum in these baseline wells are more likely related to mining activities.

No median MCL or SMCL values were exceeded in the baseline alluvial groundwater samples.

2.3.2 Areal Extent of Injured Groundwater

The areal extent of injured bedrock groundwater in the Butte Hill area is based upon subsurface mine projection maps and the farthest extent of underground mining as projected to the surface. The total area above the East Camp is approximately 166 million square feet; the total area above the West Camp is approximately 14.3 million square feet; the total area above the Outer Camp is approximately 1.7 million square feet; and the areal extent of injured groundwater in the Berkeley Pit is approximately 21.3 million square feet. Thus the total areal extent of injured groundwater associated with the bedrock aquifer in the Butte Hill area is approximately 201 million square feet (7.22 square miles or 4,621 acres).

The areal extent of injured alluvial groundwater in the Butte Hill area was estimated using the plume of groundwater concentrations exceeding the SMCL for sulfate, which is the largest contaminant plume in this area. The areal extent of the sulfate plume is approximately 18 million square feet (0.65 square miles or 413 acres).

The areal extent of injured alluvial groundwater in Area One was also determined using the sulfate plume, which was the largest contaminant plume in this area (a composite of all contaminant plumes in this area, however, would be larger). The sulfate plume has an area of approximately 24 million square feet (0.88 square miles or 562 acres). The cadmium plume is the second largest plume of injured groundwater in this aquifer. This plume, which overlaps much of the sulfate plume, has a projected area of approximately 23 million square feet (0.83 square miles or 538 acres).

2.3.3 Volume of Injured Groundwater

The volume of contaminated groundwater associated with the Butte Hill bedrock aquifer was also estimated using subsurface mine projection maps. A "fracture porosity" was assigned to the bedrock aquifer and a "mined porosity" was used to account for the void space of the underground workings. The fracture porosity was conservatively estimated to be 1.0% and the mined porosity was estimated to be 0.23%. The volume of contaminated water in the Berkeley Pit was added to the volume of the contaminated groundwater in the bedrock and underground workings. Total volumes were calculated for two conditions: (1) the present level of groundwater in the bedrock and the pit (i.e., at an elevation of 5040 USGS datum); and (2) the elevation at which it is anticipated remedial action will be implemented (i.e., at 5410 USGS datum). The total volume of contaminated bedrock water which presently exists was thereby estimated to be 183,000 acre feet; and the total volume of contaminated bedrock water at the anticipated remedial action level is 344,019 acre feet.

The volume of injured groundwater in the Butte Hill alluvial aquifer, based upon the areal extent of the sulfate plume, an estimated depth of 130 feet and an estimated 20% porosity, is 10,744 acre feet.

In Area One the volume of injured groundwater was also based upon the sulfate plume. Cross-sectional isopleth maps were used to estimate the depth of injured groundwater and a 20% porosity was used. The volume of injured groundwater in the sulfate plume was estimated to be 11,590 acre feet. The second largest plume (cadmium) has an estimated volume of approximately 10,000 acre feet.

2.3.4 Flux or Yield of Injured Groundwater

The yield of injured groundwater in the bedrock aquifer was based upon the pumping rate from the Kelly Mine during the time of mining operations. The flow required to maintain water levels below mine workings represents the yield of the injured groundwater associated with the underground mine workings. This yield is estimated at 6,900 gpm or 11,136 acre feet per year.

The average flux of the injured alluvial groundwater in the Butte Hill area was estimated using the flux of the sulfate plume; this was estimated to be 47 acre feet per year. The flux of injured groundwater flowing through the contaminated aquifer in Area One was estimated to be 2,922 acre feet per year. This was based upon the estimated net groundwater discharge to Silver Bow Creek.

2.4 Recoverability

Groundwater in the alluvial and bedrock aquifers is contaminated with inorganic substances — metals, metalloids and sulfate — which generally are not capable of being biologically degraded or transformed into less toxic or mobile species. These substances will continue to injure the alluvial and bedrock groundwater in the Butte area for hundreds of years, absent removal of the sources or implementation of effective *in-situ* remediation or restoration techniques.

Furthermore, assuming that the sources of contamination will not be removed, contaminants can be expected to be transported in the future and thereby increase the size of hazardous substance plumes, especially in the upper MSD area. In Lower Area One, groundwater discharge to Silver Bow Creek limits the lateral extent of groundwater contamination, but the extent of contamination with depth may increase over time.

3.0 ANACONDA GROUNDWATER RESOURCES

3.1 Introduction and Site Description

This section addresses the groundwater resource injuries associated with the Anaconda Smelter Superfund Site and the Warm Springs Ponds Unit, both located in or near the City of Anaconda. (See Figure 3-1.) This section is a summary and overview of the "Anaconda Groundwater Injury Assessment Report," by Dr. William W. Woessner dated February 20, 1993).

Disposal of solid mining wastes, milling debris and smelting by-products in waste piles and settling ponds in the Anaconda area occurred over the last 110 years. Over 15 square miles of land has been the subject of such disposal, including the Anaconda and Opportunity Ponds, portions of the Old Works and Smelter Hill Operable Units, and Warm Springs Ponds. These mining and processing wastes contain elevated concentrations of hazardous substances and have caused significant injury to the area's groundwater.

3.1.1 Geology of the Study Area

The Southern portion of the Deer Lodge Valley formed between 60 and 40 million years ago when a bedrock block moved down relative to the surrounding rock, forming a structurally controlled basin. The Flint Creek Range, which borders the valley to the west, is composed of Precambrian to Tertiary igneous, metamorphic and sedimentary rocks that have been subjected to uplift, faulting and erosion. The Anaconda Smelter site was located on bedrock just west of the valley floor. Smelter Hill is primarily composed of light colored and fine to medium grained rhyolitic tufts.

The southern portion of the Deer Lodge valley is filled with Tertiary sediments and Quaternary valley alluvium. Tertiary sediments in some areas are over 2000 feet thick. Semi-consolidated siltstone, sandstone, and conglomerate comprise about three-fourths of the basin fill. The upper 200 to 300 feet of material is composed of unconsolidated valley fill material weathered from the volcanic, sedimentary and crystalline bedrock slopes. Quaternary alluvium covers most of the southern end of the valley floor, and is composed of mostly coarse glacial outwash from Silver Bow Creek, Mill Creek, Warm Springs Creek and Lost Creek drainages. Quaternary deposits range in thickness from 10 feet near the Clark Fork River to 100 feet near stream canyon mouths and average 25 feet thick.

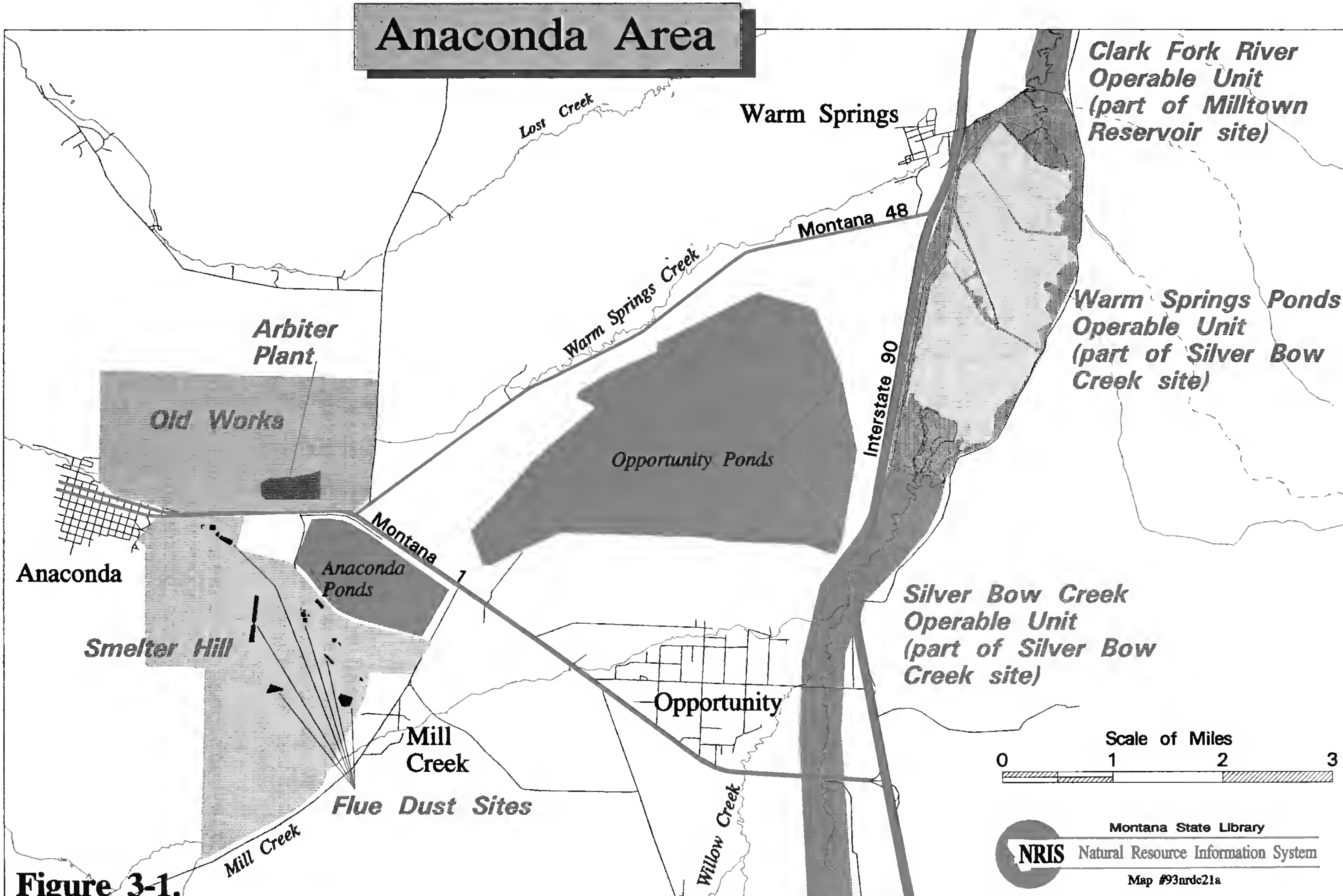

Anaconda Area
Clark Fork River
Operable Unit
(part of Milltown
Reservoir site)
Warm Springs
Lost Creek
Montana 48
Warm Springs Creek
Warm Springs Ponds
Operable Unit
(part of Silver Bow
Creek site)
Arbiter
Plant
Old Works
Opportunity Ponds
Interstate 90
Anaconda
Montana 1
Anaconda
Ponds
Smelter Hill
Silver Bow Creek
Operable Unit
(part of Silver Bow
Creek site)
Opportunity
Mill
Creek
Flue Dust Sites
Mill Creek
Willow Creek
Scale of Miles
0 1 2 3
Montana State Library
NRIS Natural Resource Information System
Map #93nrdc21a

Figure 3-1.

3.1.2 Hydrogeology of the Study Area

Three water-bearing rock or sediment units (aquifers) are located in the study area. Groundwater is found in the Quaternary glacial outwash and floodplain deposits (the alluvial aquifer), the underlying finer-grained Tertiary sediments (the tertiary aquifer), and in the fractured bedrock of the southern portion of the Deer Lodge Valley (the bedrock aquifer). Primary recharge areas for the alluvial, Tertiary, and bedrock aquifers include: 1) lateral groundwater flow from the mountains located on the west side of the valley; 2) groundwater flowing under mountain stream and creek valleys; 3) losing reaches of stream channels and ditches; and 4) direct precipitation and infiltration through permeable substrate.

Groundwater flow in the Anaconda area is generally north and east towards the Clark Fork River. Flow in the immediate vicinity of the river, including the Warm Springs Ponds area, is northward. Groundwater discharges to the Clark Fork River and to lower reaches of tributary creek channels and ditches. Groundwater flow in Warm Springs Ponds area is generally northward, although some water flows westward through the ponds berms and discharges to the Mill-Willow By-Pass.

3.2 Groundwater Injury Determination

3.2.1 Sources of Hazardous Substances

Both primary and secondary mining, milling and smelting related sources release hazardous substances to groundwater in the Anaconda area. Primary sources include concentrator wastes, slag piles, tailings, and waste rock piles. Secondary sources of contamination include: streamside tailings; streambed sediments; soils and aquifer materials contaminated by primary sources; surface salts; and smelter airfall. Hazardous substances identified in source materials in the study area include compounds of arsenic, cadmium, copper, lead, and zinc.

The principal sources of hazardous substances to groundwater associated with the Smelter Hill site are surface soils contaminated by waste disposal and smelter emissions. Infiltration of precipitation through heavily contaminated soils has resulted in leaching from the top soil layers and subsequent formation of metal-rich precipitates in fractures in the unsaturated zone. Thus the unsaturated zone serves as a secondary source of hazardous substances to groundwater.

The principal sources of hazardous substances associated with the Warm Springs Ponds Operable Unit are pond sediments derived from mining and processing wastes from Butte and Anaconda. The Ponds cover an area of approximately 4 square miles and contain approximately 19 million cubic yards of tailings and heavy metal

contaminated sediments and sludges. These tailings and contaminated soils contain elevated concentrations of hazardous substances and are void of vegetation or sparsely vegetated.

The Anaconda and Opportunity Ponds were built to settle tailings from process waste water. During smelter operations over 3.8 million gallons per day of process waste water including tailings slurry, entered the Anaconda Ponds, and over 30.1 million gallons per day of waste water flowed into the Opportunity Ponds. For many years portions of the flow of Silver Bow Creek was also diverted to Opportunity Ponds. Thus these mine waste laden waters were a significant source of hazardous substances in the groundwater beneath these ponds. Disposal practices allowed infiltration of process water through tailings containing hazardous substances. The collective volume of waste materials in the Anaconda and Opportunity Ponds is approximately 725 million cubic yards.

3.2.2 Duration of Release

Waste water, precipitation, stream water and groundwater have provided hydrological and geochemical conditions leading to the release and migration of mining and processing wastes into the groundwater system in the Anaconda area. Thus, groundwater contamination has been occurring since about 1884. Infiltration of precipitation and groundwater saturation of wastes continue to release contaminants today.

3.2.3 Pathway Determination

The primary pathways for contamination of the Anaconda area groundwater aquifers are:

1. Infiltration of contaminated settling pond waters, derived from smelter waste-water;

2. Historical and ongoing infiltration of precipitation and snow melt through sources of hazardous substances which leaches and transports hazardous substances to down-gradient groundwater;

3. Rising of capillary groundwater to sources of contamination in the unsaturated zone, which leaches and transports hazardous substances to down-gradient groundwater during an infiltration event;

4. Inundation and leaching of source materials and contaminated sediments by changes in groundwater level; and

5. Flow of contaminated water to down-gradient uncontaminated ground and surface water.

The fractured bedrock underlying Smelter Hill permits infiltration of precipitation and surface water, and lateral flow of groundwater from the mountains to the west of Smelter Hill. Natural recharge water becomes contaminated as it dissolves soluble hazardous substances in contaminated soils, wastes, and rock of the unsaturated zone. Fractures in the bedrock aquifer are filled with metal rich precipitates derived from percolation of groundwater laden with dissolved hazardous substances. In addition, a portion of the 17.4 million gallons/day of process water used on Smelter Hill contributed to groundwater recharge. Interconnected fractures and joints allow transport of infiltrating water; groundwater contaminated with hazardous substances has been detected in the upper 60 to 120 feet of the fractured bedrock system.

Large volumes of the waste-water historically discharged to the Anaconda and Opportunity Ponds, infiltrated the permeable tailings and recharged the underlying alluvial groundwater system. The addition of this water to the valley groundwater system altered local flow directions. Added to that was recharge from precipitation infiltration, concentrated in the large areas of barren unconsolidated waste piles and now-dry tailings ponds. This recharge continues to contaminate the groundwater, which flows beneath Opportunity Ponds and discharges to the Mill-Willow By-pass, Warm Springs Creek, and the Clark Fork River.

In Warm Springs Ponds, pond water seeps through contaminated pond berms and bed sediments and releases contaminants to the underlying groundwater. In addition, tailings occupying the Clark Fork River floodplain north of the ponds are saturated by a high water table and thus metals are released from the tailings into the groundwater. Groundwater flows north below and downstream from the Warm Springs Ponds, contaminating the coarse grained sediments lying below and north of the ponds. The seepage from the ponds has contaminated groundwater up to 40 feet below the water table.

3.2.4 Injury Determination

Samples of groundwater from some 200 wells were used to characterize the Anaconda groundwater system. These water quality data revealed concentrations of contaminants in many wells which exceeded primary and secondary drinking water standards and, therefore, are indicative of injured groundwater. In the Smelter Hill/Old Works/Anaconda Ponds area, groundwater exceeded MCLs or SMCLs for aluminum, arsenic, cadmium, chromium, fluoride, iron, manganese, mercury, sulfate, and zinc. In the Opportunity Ponds area, groundwater exceeded MCLs or SMCLs for arsenic, cadmium, fluoride, iron, manganese, sulfate, and zinc. In the Warm Springs

Ponds area, groundwater exceeded MCLs or SMCLs for arsenic, cadmium, fluoride, iron, manganese, and sulfate.

3.3 Groundwater Injury Quantification

3.3.1 Baseline Conditions

Water quality data from eighty-one wells in the vicinity of the contaminated aquifer were used to determine baseline. Median concentrations of analytes in the groundwater from these wells did not exceed drinking water standards.

3.3.2 Areal Extent of Injury

The extent of injured groundwater was determined by plotting positions of wells for which one or more water quality standard was exceeded. Areas of exceedance were determined using two methods: Model 1, a linear interpolation method; and Model 2, a computer automated, weighted average interpolation method, using a search radius of 3,300 feet.

Areas of greatest contamination are centered on Smelter Hill, Anaconda Ponds, Opportunity Ponds, and in the vicinity of Warm Springs Pond 1. The composite area overlying the contaminated groundwater is greater than 25 square miles. (See Figure 3-2.)

3.3.3 Volume of Injured Groundwater

The volume of the contaminated groundwater was determined by multiplying areas of exceedances by estimates of saturated thickness and porosity of the contaminated aquifer.

Table 3-1 presents volume estimates, based on Models 1 and 2, for some of the larger plumes of contaminated groundwater. The best estimate of the composite volume of all of the contaminant plumes in the Anaconda area is 327,400 acre-feet (the average of Models 1 and 1). The best estimate of the composite volume of groundwater exceeding standards for arsenic, cadmium, and zinc is approximately 142,400 acre-feet.

3.3.4 Flux of Injured Groundwater

The composite discharge of groundwater contaminated with hazardous substances and other wastes ranges between 8,000 and 9,000 acre feet/year in the vicinity of Opportunity Ponds and is estimated to be about 1,100 acre-feet/year at Warm Springs Ponds.

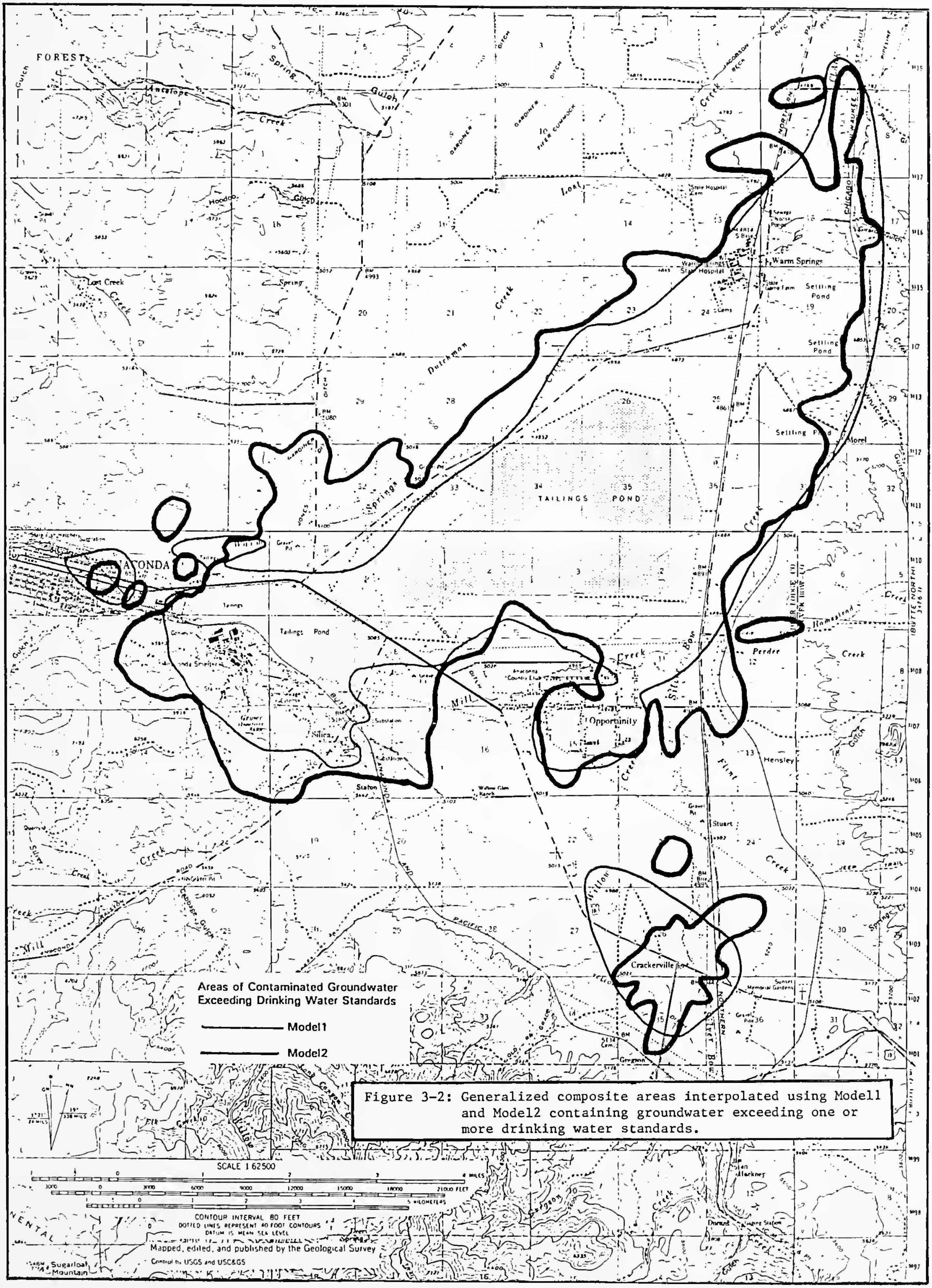


Figure 3-2: Generalized composite areas interpolated using Model1 and Model2 containing groundwater exceeding one or more drinking water standards.

Table 3-1 Locations and volume estimates of injured groundwater.			
Hazardous Substance	Locations of Exceedances	Volume Midpoint (acft) Model 1	 Model 2
Arsenic (MCL = 50 μg/l)	Smelter Hill, Old Works, Anaconda Ponds area; Opportunity Ponds area; north end of the Warm Springs Ponds.	84,350	123,000
Cadmium (MCL = 5 μg/l)	Smelter Hill, Old Works; Mill Creek; Opportunity Ponds; Silver Bow Creek floodplain; Mill-Willow Bypass area; Warm Springs Pond 1; Clark Fork River headwaters	59,200	91,000
Zinc (SMCL = 5000 μg/l)	Smelter Hill; Anaconda Ponds; Opportunity Ponds	25,400	25,850
Fluoride (SMCL = 2000 μg/l)	Smelter Hill, near stack; Anaconda Ponds; Opportunity Ponds; Warm Springs Ponds	77,700	36,950
Sulfate (SMCL = 250 mg/l)	Smelter Hill, Old Works, Anaconda Ponds, Opportunity Ponds, Warm Springs Ponds, Silver Bow Creek/Crackerville area.	178,150	238,050
Iron (SMCL = 300 mg/l)	Smelter Hill, Old Works, Anaconda Ponds, Opportunity Ponds, Warm Springs Ponds.	136,200	226,750
Manganese (SMCL=50 μg/l)	Smelter Hill, Old Works, Anaconda Ponds, Opportunity Ponds, sections of towns of Anaconda and Opportunity.	204,950	290,450
Composite Volume*	Anaconda Regional Area	271,050	383,750
*Because contaminant plumes overlap, composite volume is less than the sum of individual plumes volumes.			

3.4 <u>Recoverability</u>

Currently, large volumes of groundwater remain contaminated and thousands of tons of hazardous substances remain present on the surface of the site. Recharge infiltration through Anaconda and Opportunity Ponds surfaces will continue to acidify and mobilize hazardous substances and other constituents. Leaching mechanisms in the tailings materials will continue to release hazardous substances to the underlying groundwater until sulfides in the tailings are completely oxidized. Thus the injury to the groundwater will continue for hundreds to thousands of years.

Seepage from Warm Springs Ponds will also continue as long as no permeability controls are implemented at the pond site. Groundwater contamination in the Warm Springs area will continue indefinitely.

4.0 MILLTOWN GROUNDWATER RESOURCES

4.1 Introduction and Site Description

This section addresses injury to groundwater in the vicinity of Milltown Dam and near the town of Milltown five miles east of Missoula, Montana. This section is a summary and overview of the "Milltown Groundwater Injury Assessment Report," by Dr. William W. Woessner, dated March 10, 1993.

Milltown Dam was constructed in 1907-1908 at the confluence of the Clark Fork and Blackfoot rivers. (See Figure 4-1.) It is the first dam on the Clark Fork River downstream from the Warm Springs Ponds. Over 6 million cubic yards of contaminated sediments occupy the reservoir behind the dam. Contaminants released from these sediments have caused injury to the groundwater underlying and adjacent to the Milltown Reservoir.

4.1.1 Geology of the Study Area

Mountains surrounding Milltown are composed of Precambrian argillite, quartzite and limestone metasediments of the Belt Series. The valley floor is underlain by Quaternary alluvium and Precambrian bedrock. Valley alluvium consists of inter-bedded sand, gravel and boulders with some clay lenses. Alluvium thickness varies from 20 feet under the fine-grained reservoir sediments to over 150 feet in the vicinity of the plywood mill north of Milltown. Bedrock underlying the alluvium is composed of metasediments of the Belt Series. Reservoir sediments are fine-grained sand, silt and clay approximately 29 feet thick near the dam and thinning upstream.

4.1.2 Hydrogeology of the Study Area

At Milltown Dam the water table is at the surface of the reservoir sediments; the water table is 30 to 40 feet below land surface in the town of Milltown. Groundwater recharge is from direct precipitation, leakage from the reservoir, and by lateral flow from the mountain boundaries and the upstream valley alluvium. Groundwater movement is from the reservoir sediments to the northwest, parallel to the Clark Fork and Blackfoot rivers. The hydraulic conductivity of the sand, gravel and cobble aquifer varies widely between the finer fraction and the cobble zones.

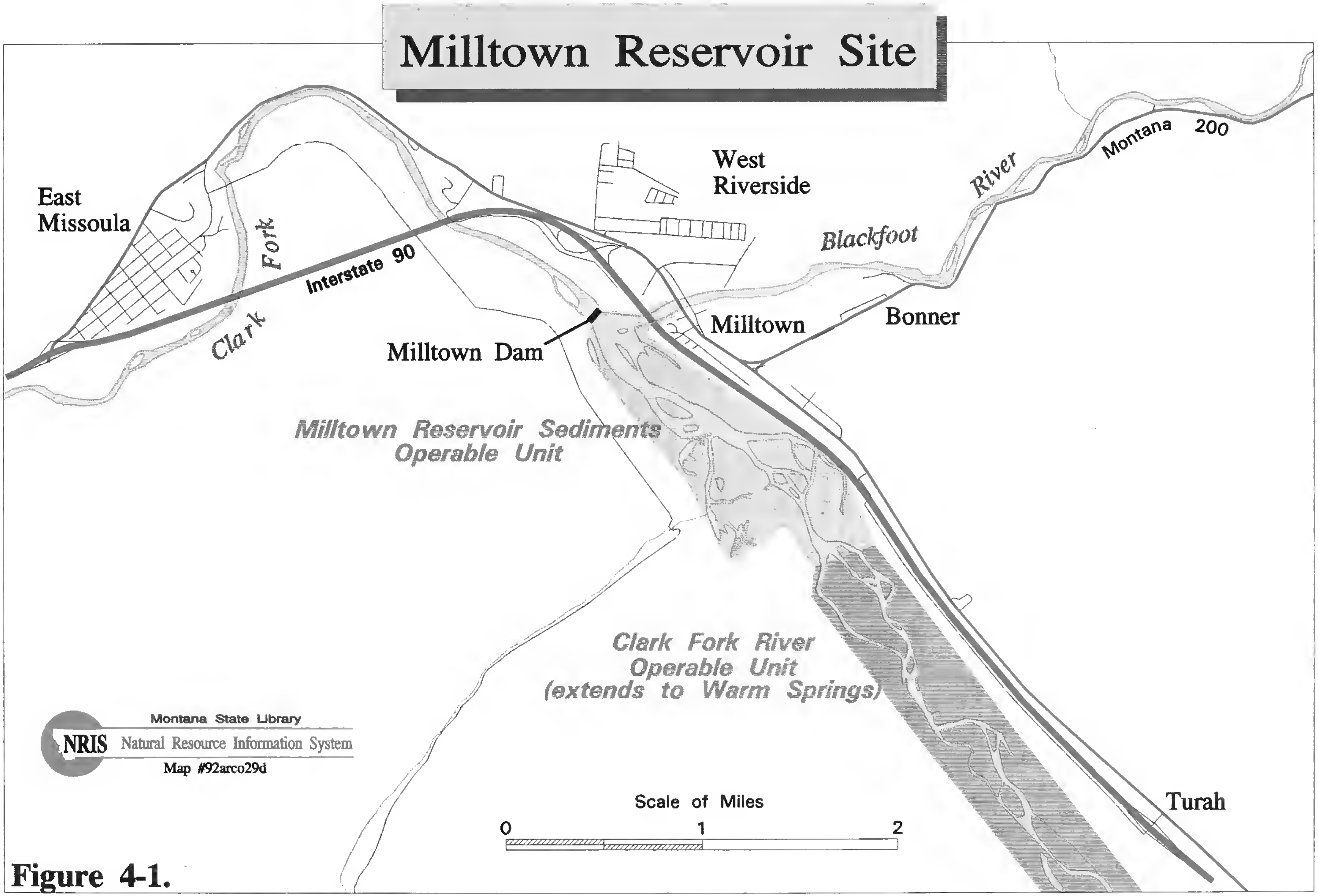

Milltown Reservoir Site
East
Missoula
Clark Fork
Interstate 90
West
Riverside
Blackfoot River
Montana 200
Milltown
Bonner
Milltown Dam
Milltown Reservoir Sediments
Operable Unit
Clark Fork River
Operable Unit
(extends to Warm Springs)
Turah
Montana State Library
NRIS Natural Resource Information System
Map #92arco29d
Scale of Miles
0
1
2

Figure 4-1.

4.2 Groundwater Injury Determination

4.2.1 Sources of Hazardous Substances

The source of contaminated groundwater underlying the reservoir and southern portion of the town of Milltown is the fine-grained sediment trapped behind Milltown Dam. The principal data supporting this conclusion are: 1) the presence of large volumes of arsenic and metal contaminated sediments found in the reservoir; 2) the presence of hydraulic gradients that direct groundwater movement from reservoir sediments to adjacent contaminated wells; and 3) arsenic and metal concentrations which are highest in groundwater beneath the reservoir and decrease in concentration towards the affected wells.

Since 1908, bedload and suspended load from the upper Blackfoot and Clark Fork Rivers have been impounded by Milltown Dam. These sediments have nearly filled the reservoir. The sediments contain arsenic and metals originating from upstream mining and processing operations centered in Anaconda and Butte. Table 4-1 contains an estimate of the total tons of various contaminants present in the reservoir sediments.

Table 4-1
Estimate of Tons of Contaminants Found in the Milltown Reservoir Sediments

Substance	Tons
Arsenic	2,100
Barium	2,000
Cadmium	70
Copper	13,100
Chromium	350
Manganese	9,200
Lead	1,700
Zinc	19,000

4.2.2 Duration of the Release

Contaminants are released from the reservoir sediments as water flows through them and into the underlying basal floodplain material. It is probable that this process began almost immediately after dam completion in 1908. This release of

hazardous substances continues today with only small seasonal variation.

4.2.3 Pathway Determination

The reservoir sediments are permeable and saturated to the reservoir pool level. A groundwater system is present in the reservoir sediments. It is recharged principally from reservoir pool water and also by direct precipitation. Reservoir groundwater generally flows towards the north and northwest, and downward. Metals and arsenic are released as water flows through submerged oxidized and reduced zones in the sediment. Reservoir stage fluctuations result in a rise and fall of the water table in the sediments which in turn causes a migration of the redox boundary. This process de-stabilizes the geochemical equilibrium and allows mobilization of arsenic and metals.

Arsenic, metals and TDS released from the reservoir sediments migrate with the groundwater flow system. Large vertical gradients exist between the fine-grained reservoir sediments and the adjacent coarse saturated material. Groundwater emanating from these sediments flows downward and north-northwest, contaminating the aquifer under the sediments and under the southwestern portion of Milltown.

4.2.4 Injury Determination

Samples of groundwater from 174 wells in the alluvial aquifer were used to characterize the Milltown groundwater system. Median contaminant concentrations in many wells exceeded drinking water standards for dissolved arsenic, iron, manganese, sulfate, and total dissolved solids (TDS). Thus the groundwater resource has been injured.

4.3 Groundwater Injury Quantification

4.3.1 Baseline Conditions

Groundwater in the Milltown region is used for domestic and industrial supply. Though the water quality from wells directly associated with monitoring the contaminant plume typically exceed drinking water standards, water from other wells in the region appears to be unaffected by the contaminated groundwater. Wells in which none of the reported water quality values exceeded drinking water standards were selected to represent baseline groundwater quality. (See Table 4-2.) Median contaminant concentrations in these wells are similar to those found in the Missoula Aquifer located five miles to the west, which is similar in character to the aquifer underlying Milltown.

4.3.2 Areal Extent of Injured Groundwater

The extent of injured groundwater was determined by plotting positions of those wells at which one or more drinking water quality standards were exceeded. The area of exceedance of each substance was determined using two methods, Model 1, a linear interpolation method, and Model 2, a computer automated weighted average interpolation method. (See Figure 4-2.) The total area of contaminated groundwater was determined by planimetering the areas of exceedance.

4.3.3 Volume of Injured Groundwater

The volumes of contaminated groundwater were determined by multiplying the planimetered area of contamination by estimates of aquifer thickness and porosity. Best estimates of the volumes of injured groundwater are summarized in Table 4-2. The manganese plume volume encompasses the composite plumes of arsenic, iron and TDS; therefore, the manganese plume of approximately 4,410 acre-feet represents the extent of injured groundwater in this area.

4.3.4 Flux of Injured Groundwater

The rate and amount of contaminant releases from reservoir sediments were calculated by estimating flow of groundwater and median concentrations of arsenic, iron and manganese through northwest to southeast cross sectional areas of the injured aquifer. A mean hydraulic conductivity of 8,600 feet/day was used to represent the transmission properties of the coarse-grained aquifer and Darcy's Law was used to calculate the groundwater discharge (i.e., flux). (See Table 4-2).

Table 4-2
Summary of Volumes
Flux of Injured Groundwater in Milltown

Substance	Volume (Acre-feet)	Flux (Acre-feet/year)
Arsenic	2140	27,000
Iron	3108	50,400
Manganese	4410	117,100

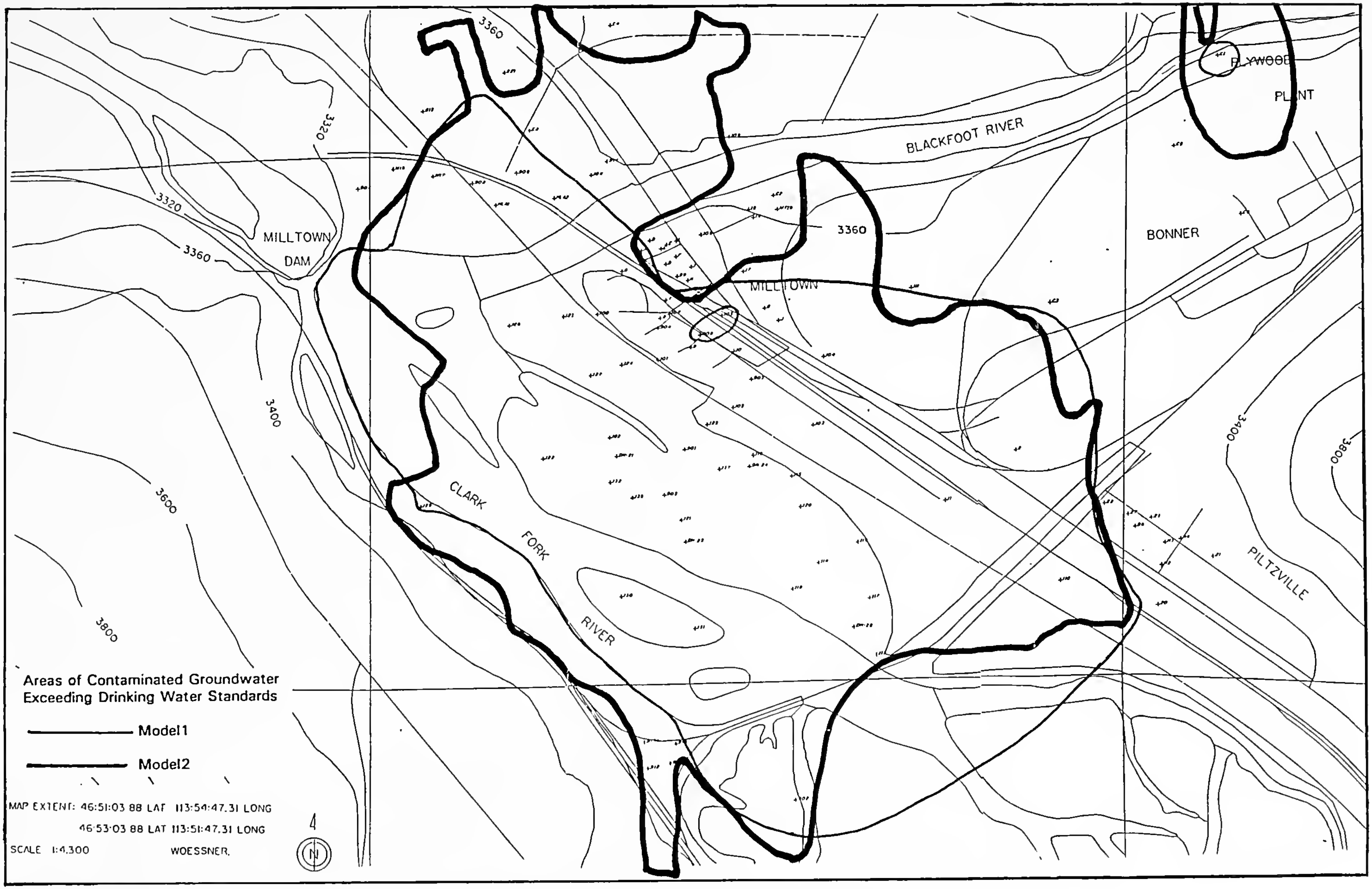


Figure 4-2: Generalized areas interpolated using Model1 and Model2 containing groundwater exceeding drinking water standards for dissolved manganese, 50ug/1.

Median contaminant concentrations were multiplied by the discharge passing through the cross sectional areas to calculate the pounds of metals and arsenic leaving the source area. Under this analysis it is estimated that the reservoir sediments contaminate the Milltown groundwater system with over 27 tons of arsenic, 1,000 tons of iron and 1,600 tons of manganese annually. (See Table 4-3.)

Table 4-3
Mass Flux of Arsenic and Metals from
the Milltown Reservoir to the Alluvial Groundwater System Compared with a Baseline Flux

Substance	Lb/day @ Milltown	Lb/day @ Baseline	Ratio of Milltown to Baseline
Arsenic	147	0.7	210
Iron	5,608	16.0	350
Manganese	9,045	14.5	625

4.4 Recoverability

Contamination of groundwater underlying Milltown Reservoir and the adjacent sand and gravel aquifer is a result of the mobilization of arsenic and metals from contaminated fine-grained reservoir sediments. Over 6 million cubic yards of contaminated sediments are currently trapped behind Milltown Dam. Sediment sources upstream are also highly contaminated and natural migration of sediments downstream continues to add contaminated sediments to the reservoir. Unless remediated, the injury to the aquifer will persist for hundreds to thousands of years.

5.0 MONTANA POLE GROUNDWATER RESOURCES

5.1 Introduction and Site Description

This section is a summary and overview of the "Montana Pole Treatment Plant Groundwater Injury Assessment," by John Metesh dated April, 1993. This section addresses injury to groundwater resources associated with the Montana Pole Superfund Site in southwest Butte. (See Figure 5-1.) Operations at the Montana Pole site began in July of 1946 and were discontinued in 1984. Timber was dried and pressure treated with a diesel/PCP mixture. An unknown volume of hazardous substance was released onto the site during treatment plant operations.

5.1.1 Geology of the Study Area

The Montana Pole site is located in the southern portion of a granitic mass known as the Boulder Batholith. The site is located on the edge of the Butte mining district. The depth to bedrock beneath the site is variable and ranges from approximately 11 feet to 47 feet. The bedrock is overlain by Quaternary and Tertiary alluvium and colluvium. These materials are derived from the high mountains to the east and south as well as the smaller hills north and west. The site is located on the southern portion of a wetlands area that has been filled in by tailings and other waste materials. The alluvium is composed of silty sand and gravels interbedded with sandy clay.

5.1.2 Hydrogeology of the Study Area

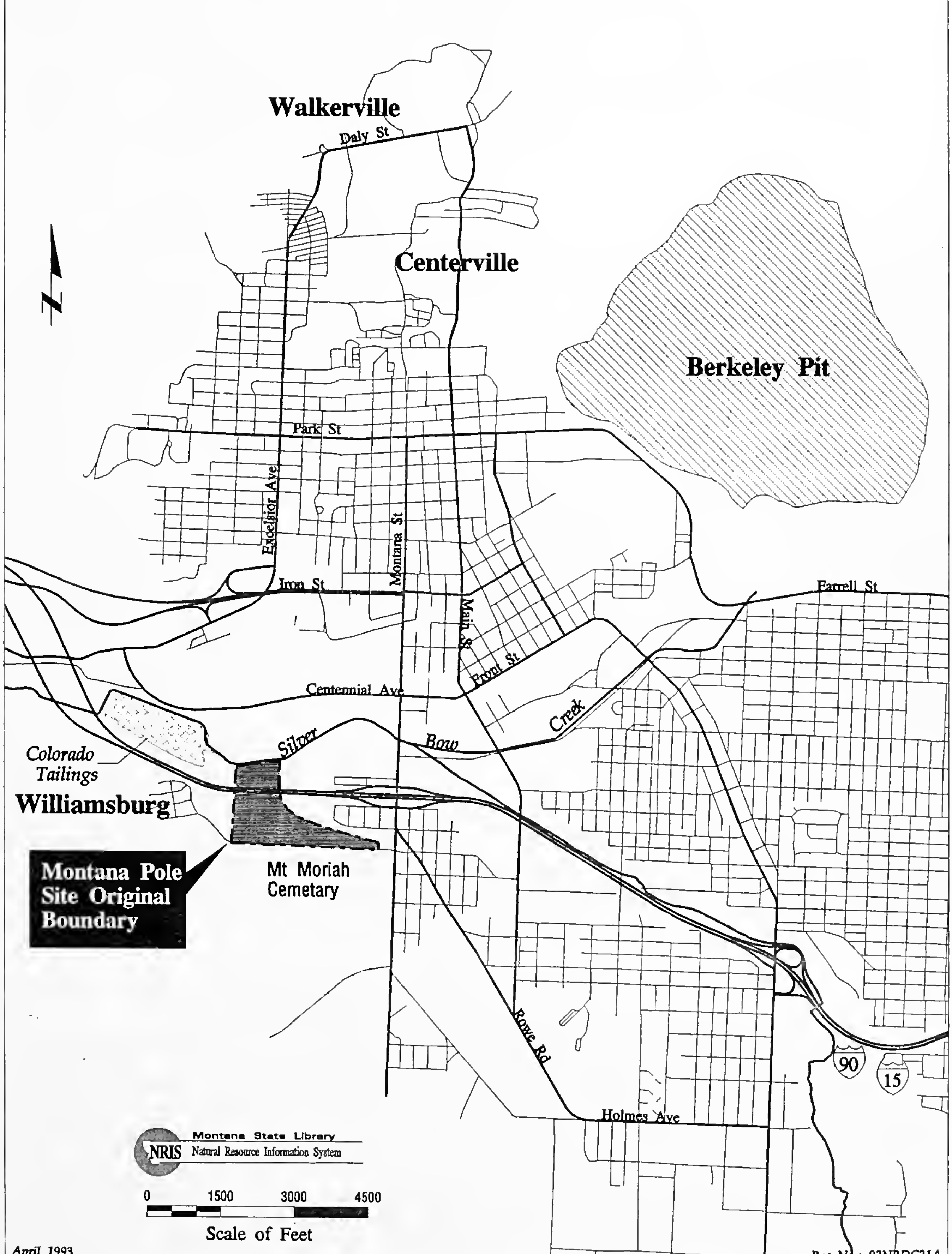
The alluvial aquifer extends beneath the entire site. Groundwater flow in the aquifer is generally from southeast to northwest toward Silver Bow Creek, and the creek, which lies on the northern boundary of the site, is the discharge area for the aquifer. Depth to the water table ranges from approximately 5 to 20 feet. The hydraulic connection between the alluvial aquifer and bedrock aquifer beneath the site is uncertain.

5.2 Groundwater Injury Determination

5.2.1 Sources of Hazardous Substances

The most significant sources of contamination at the site are contaminated soils. The soils were contaminated either directly from processing and treatment of the timber, or from spills of hazardous substances (i.e., diesel fuel/PCP) onto the ground surface. Timber was dried and treated with a diesel fuel/PCP

Figure 5-1: Montana Pole



mixture in the retorts. The discharge stream emanating from the retorts was a primary source of soil contamination.

The zone between the highest and lowest seasonal groundwater level acts as a secondary source of hazardous substances. Floating hazardous substances are repeatedly smeared over the interval as water-levels fluctuate, enhancing the mass transfer of PCP and other organic contaminants to groundwater.

5.2.2 Duration of Release

Depending on soil conditions, hazardous substances would likely have reached the water table within a few months of initial release. Releases of hazardous substances to groundwater continues today. In addition, PCP is released to Silver Bow Creek from seeps along the stream bank. (Releases to the creek have been reduced by recent EPA activities.)

5.2.3 Pathway Determination

PCP and other hazardous substances are leached downward to the water table, and since these hazardous substances are lighter than water, most remain floating on the water. These contaminants are then released into the groundwater by dissolution. The result is co-existing plumes of undissolved and dissolved hazardous substances. The primary pathway for groundwater contamination thus involves free-phase PCP that has leached through the unsaturated material. Dissolution of PCP is enhanced by seasonal groundwater fluctuations which increases the contact area between the groundwater and the free-phase hazardous substances.

There are two primary factors that affect the mobility of PCP: 1) the physical relationship of the contact between hazardous substances and groundwater; and 2) the relationship between the dissolved organic constituents and the aquifer material. The grain-size of the alluvial material beneath the Montana Pole site ranges from sand to clay. Thus, the oil/water contact surface area and, as a result, the rate of dissolution of PCP is likely to be quite variable. Once dissolved into groundwater, PCP and other organic constituents are immediately subject to sorption by the aquifer material.

5.2.4 Injury Determination

Free-phase hazardous substances range in thickness from an oil sheen to approximately 3 feet in several monitoring wells on site. Hazardous substances identified at the site in soil and groundwater resources include: phenols including pentachlorophenol (PCP),

polynuclear aromatic hydrocarbons (PAHs), BTEX, 2-methylnapthalene, naphthalene, phenanthrene, dioxins and furans.

The concentration of PCP in the groundwater was reported as high as 42,900 ppm in Well 8 and is greater than 5,000 ppm in a number of other wells. This is considerably greater than the drinking water MCL of 1 ppb and MCLG of 0; therefore injury has occurred. However, concentrations decrease rapidly with distance away from the free-phase plume as a result of sorption by organic carbon in the aquifer material.

5.3 Groundwater Injury Quantification

5.3.1 Baseline Conditions

Since the principal contaminants of concern were synthetically derived and have not been associated with any other industrial sources in the vicinity of the Montana Pole site, baseline concentrations can be considered zero for both the bedrock and the alluvial aquifers. Several wells located up-gradient and away from the site were sampled and analyzed for the contaminants of concern. PCPs and PAHs were not detected in these wells.

5.3.2 Areal Extent of Injured Groundwater

PCP is the most widespread contaminant encountered at the site. When detected, the occurrence of other organic constituents was coincident with the occurrence of PCP. The total area bounded by the 1 ppb PCP isopleth is approximately 44 acres. (See Figure 5-2.) Although elevated concentrations of metals were detected in wells near Silver Bow Creek, it is not likely that they are associated with the pole treatment process, but rather with mining and related activities in the area.

5.3.3 Volume of Injured Groundwater

The vertical extent of contamination was based on PCP concentrations from wells completed at depth. Using an average depth to water of 12 feet and an average depth to bedrock of 35 feet, the saturated thickness was estimated to be 23 feet. Using this thickness the 44 acre area of the 1 ppb isopleth, and an estimated porosity of 32%, the total volume of injured groundwater is approximately 350 acre-feet.

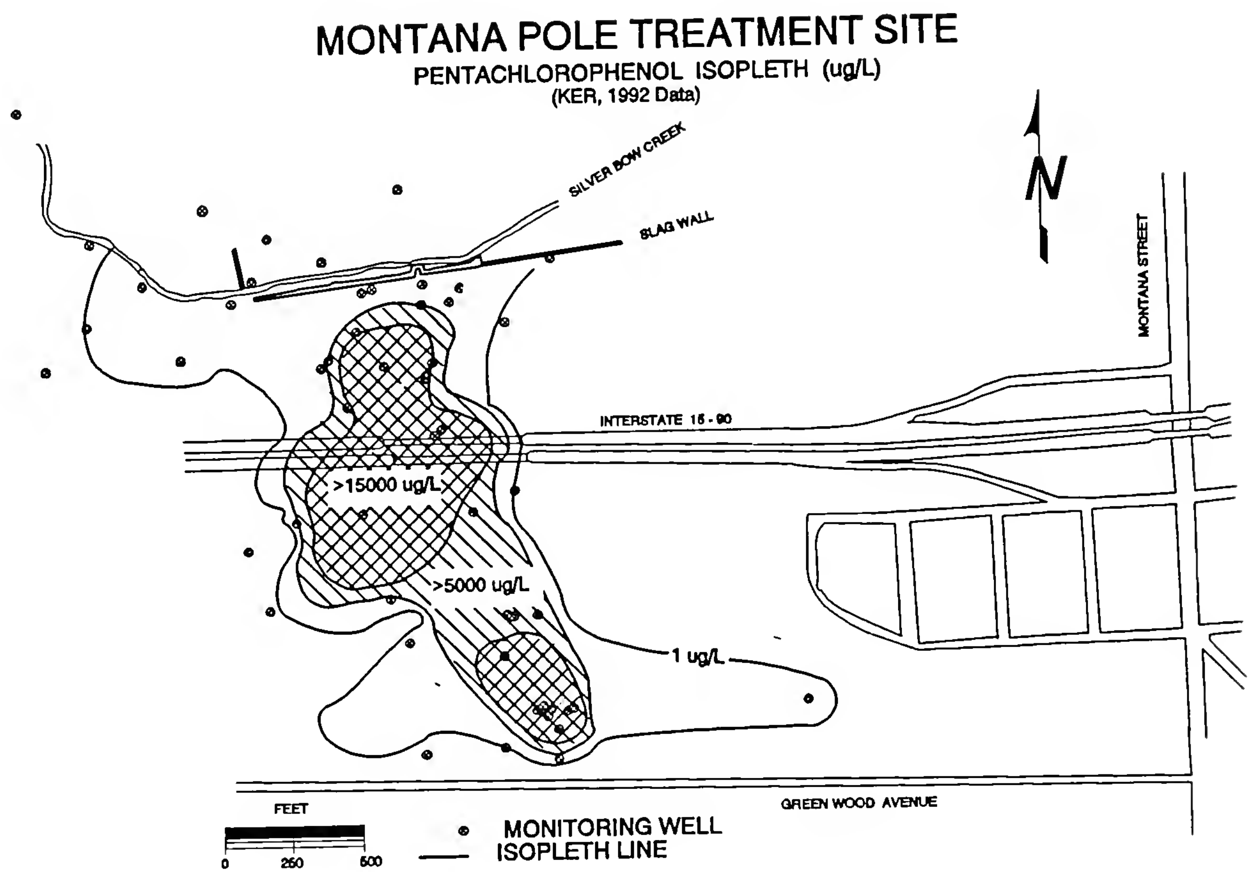

MONTANA POLE TREATMENT SITE
PENTACHLOROPHENOL ISOPLETH (ug/L)
(KER, 1992 Data)
SILVER BOW CREEK
SLAG WALL
N
MONTANA STREET
INTERSTATE 15 - 90
>15000 ug/L
>5000 ug/L
1 ug/L
GREEN WOOD AVENUE
FEET
0
250
500
MONITORING WELL
ISOPLETH LINE

Figure 5-2.

5.3.4 Flux of Injured Groundwater

The flux of groundwater through the site was calculated using Darcy's Law. The flux is approximately 2650 feet^3/day (22 acre-feet/year).

5.4 Recoverability

The total amount of hazardous substances released to the ground surface is unknown. Hazardous substances retained in the soil will be available for dissolution into the groundwater until they are depleted or removed. Without complete remediation, recovery will take hundreds to thousands of years.

6.0 ROCKER GROUNDWATER RESOURCES

6.1 Introduction and Site Description

This section is a summary and overview of the accompanying "Rocker Groundwater Injury Assessment Report", by Dr. William W. Woessner, dated January 22, 1993. The Rocker Timber Framing and Treating Plant, located approximately seven miles west of Butte in the floodplain of Silver Bow Creek (See Figure 6-1), was owned and operated by the Anaconda Company from 1909 to 1957. The plant milled and treated timbers used in Anaconda's mining operations. Timbers were preserved by immersion in a solution containing dissolved arsenic.

6.1.1 Geology of the Study Area

The site is underlain by Quaternary floodplain deposits of Silver Bow Creek and valley fill Tertiary sediments. Soil borings in the immediate vicinity reveal a heterogeneous sequence of lenses of clay, silt and sand deposits. The site appears to be underlain at about 80 feet by a deposit of "hard dense silt" of unknown thickness.

6.1.2 Hydrology of the Study Area

The water table is commonly less than 10 feet below land surface. The 60 to 70 feet of saturated material above the hard dense silt appears to be acting as an unconfined groundwater system. Hydraulic conductivity in wells classified as "shallow" (<20 feet) and "intermediate" (>20 to 60 or 70 feet) have similar average values, ranging from 2 to 5 feet/day. Conceptually, groundwater flow is generally down the valley to the west.

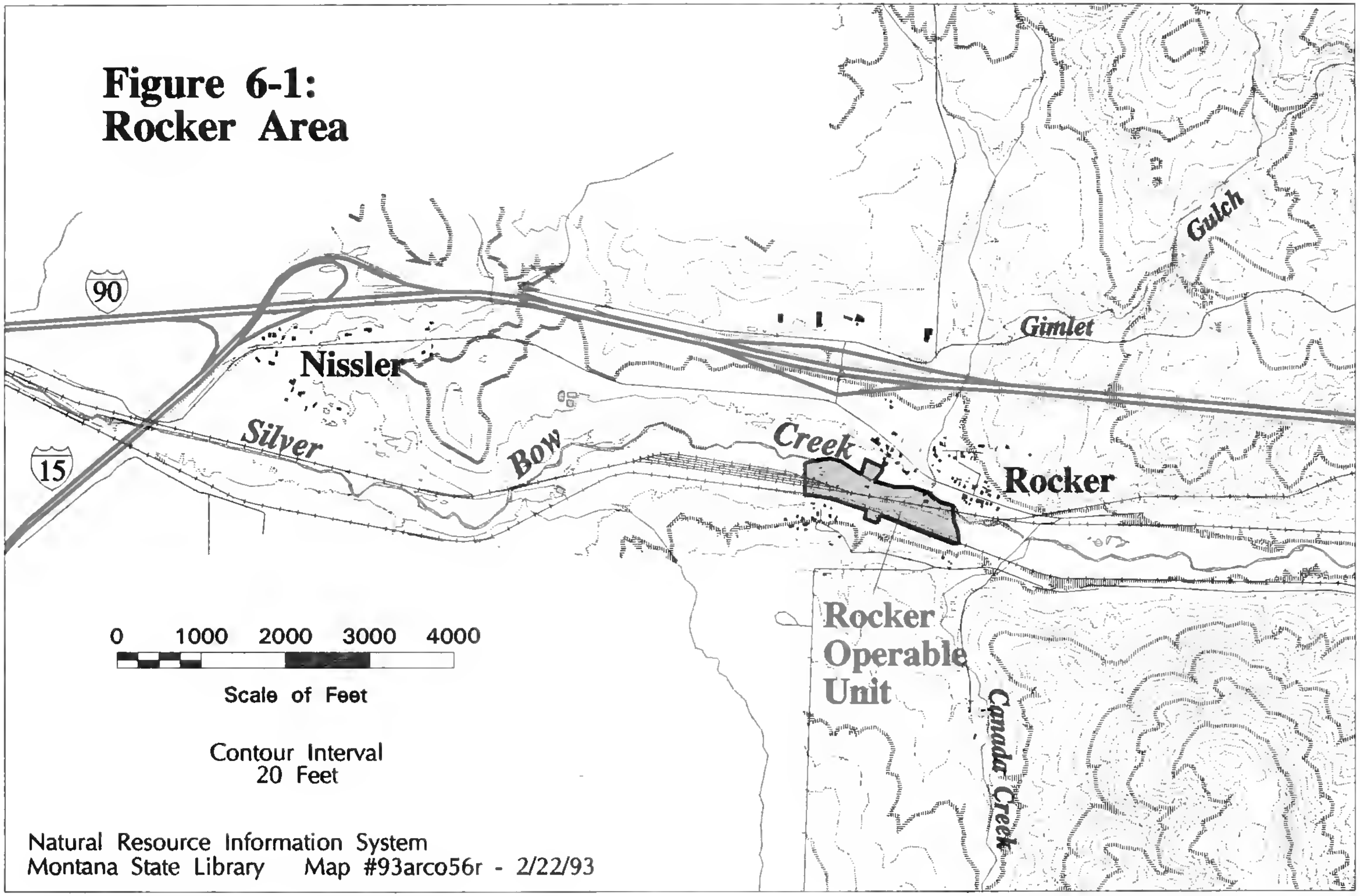


Figure 6-1:
Rocker Area
90
15
Nissler
Silver
Bow
Creek
Rocker
Gimlet
Gulch
Rocker
Operable
Unit
Canada Creek
0 1000 2000 3000 4000
Scale of Feet
Contour Interval
20 Feet
Natural Resource Information System
Montana State Library Map #93arco56r - 2/22/93

6.2 Groundwater Injury Determination

6.2.1 Sources of Hazardous Substances

Both primary and secondary sources release hazardous substances to groundwater in the study area. Primary sources are those directly derived from processing operations at the timber mill, including leakage from pits and vats used to hold arsenic solutions and organic solvents, and spills of processing fluids. Secondary sources are the result of reworking of the primary sources by physical (i.e., transport in surface water) or chemical (i.e., leaching) mechanisms. Secondary sources of hazardous substances include soils containing elevated concentrations of arsenic, cadmium, copper, lead, zinc, and PAHs, tailings and waste rock material used as railroad bed fill on-site.

In November, 1989, approximately 1,200 cubic yards of arsenic contaminated wood chips and soils were removed from the Rocker site in areas exhibiting arsenic concentrations in excess of 10,000 ppm. However, recent soil sampling has determined that surface soils containing arsenic in excess of 10,000 ppm remain at the site, and that subsurface soils have arsenic concentrations ranging up to 5000 ppm.

6.2.2 Duration of Release

Contaminants at the site have most likely been releasing hazardous substances to the groundwater aquifer since the early 1900s. Releases continue today. The seasonal variation of the water table, and infiltrating water from precipitation, perpetuate the contamination of groundwater and migration of hazardous substances at the site.

6.2.3 Pathway Determination

Organic compounds, metals, and metalloids released from treatment processes have leached vertically through soils to the water table and have contaminated the groundwater system underlying and adjacent to the site. Precipitation, percolating through contaminated soils, and possible infiltration of high waters along the creek have mobilized wastes and transported them to the shallow groundwater. Downward vertical gradients and high densities of some of the organic wastes allow wastes to move deeper in the saturated zone, contaminating part of the intermediate zone. Today, the seasonal variation of the water table and infiltrating water from recharge perpetuate the contamination of groundwater and migration of hazardous substances at the site.

6.2.4 Injury Determination

Water quality data were compiled for 37 monitoring wells at and adjacent to the Rocker site, and for 12 domestic water supply wells and one monitoring well within two miles of the site. Plumes of injured groundwater with arsenic, cadmium, copper, lead, sulfate, zinc, iron, manganese and PAH concentrations exceeding drinking water standards were identified. In addition, the site continues to contribute arsenic and PAHs to Silver Bow Creek.

6.3 Groundwater Injury Quantification

6.3.1 Baseline Conditions

Water quality data from monitoring and domestic wells within a two mile radius of the Rocker site were reviewed to determine baseline conditions. Wells with concentrations that did not exceed drinking water standards were concluded to be representative of baseline conditions and median concentrations for constituents in these wells were calculated.

These baseline wells currently provide potable water. However, extended pumping may induce the movement of contaminated groundwater to these wells, thus rendering them unpotable.

6.3.2 Areal Extent of Injured Groundwater

Exceedance maps were produced for both the shallow and intermediate zones for each contaminant. The areal extent of injury, based upon the composite area of the individual maps, was approximately 20 acres. This estimate is conservative since existing wells in the area do not define the full extent of contamination.

Water quality data from wells completed north of Silver Bow Creek indicate that contamination from Rocker area sources may have spread beneath the channel. However, contamination in the floodplain may be partially a function of contamination in streamside tailings deposits.

6.3.3 Volume of Injured Groundwater

Volumes of injured groundwater were calculated for the shallow aquifer, using an average saturated thickness of 12 feet and estimated porosity 0.40, and for the intermediate aquifer using an average saturated thickness of 30 to 40 feet and an estimated porosity 0.45. Plumes of injured groundwater included arsenic, cadmium, copper, lead, sulfate, zinc, iron, manganese, and PAHs.

The composite volume of the contaminated groundwater plume is approximately 202 acre-feet.

6.3.4 Flux of Injured Groundwater

The flux of contaminated groundwater flowing through the site down-gradient is approximately 1.8 acre-feet/year. It is likely that this flow exchanges with Silver Bow Creek. However, the area of injured groundwater associated with the Rocker site does not appear to be expanding in size.

6.4 Recoverability

Some organic contaminant concentrations may be mitigated by natural microbial action. However, natural amelioration of groundwater quality at the site is not likely in the foreseeable future, especially in the intermediate zone, as groundwater flow rates are small and contaminated aquifer material will continue to act as a source. Unless complete remediation occurs, the presence of hazardous substances in the substrate and continued natural recharge of the site will result in continued contaminant releases and groundwater contamination for hundreds of years.